STUDIES ON COASTAL ZONE FISHERY RESOURCE POTENTIAL USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM TECHNIQUES

ABSTRACT

THESIS

SUBMITTED FOR THE AWARD OF THE DEGREE OF

Doctor of Philosophy

IN

ZOOLOGY

MONOWAR ALAM KHALID

FISHERIES LABORATORY
DEPARTMENT OF ZOOLOGY
FACULTY OF LIFE SCIENCES
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

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ABSTRACT

Satellite remote sensing applications and Geographical information system (GIS) techniques are becoming an important tool to tap the vast untapped reservoirs of bio-resources from our oceans. In the present context, the study entitled "Studies on coastal zone fishery resource potential using Remote Sensing and Geographical Information System techniques," envisages an amalgamation of satellite remote sensing data (particularly Indian Remote Sensing Satellite data) and the fish catch data using various GIS techniques in finding its utility for oceanic studies.

Present study suggests a new approach through a technique of identifying fronts and features as oceanic processes in the satellite derived data. Interfacing of this data along with sea-truth data yields us a wealth of information, suggestive of identifying fishery potential in the region.

The study has been carried out in a coastal zone covering nearly 11% of the total Indian coastline from 18^{0}-21^{0}N and 84^{0}-89^{0} E in north-west Bay of Bengal in eastern India. The depth zone in the study area ranged within 30 to 300 meters. Fishery survey data, satellite data, Naval hydrographic charts and archieved data were used for the present study.

Graphic transformation of data and its overlay through data interpolation and rasterisation has been explained in two phases. Phase-I explaining the tran

spatio-temporal fishery survey data coll

during sea cruises. Whereas, phase-II explains the transformations made to satellite data of IRS-1B LISS-I procured from National Remote Sensing Agency, Hyderabad as geo-located data in four bands in three CCT's for three different seasons and averaged.

Redundant?

Twenty nine fish species were selected for explaining the characteristics of fish distribution and their temporo-spatial trends. Species-wise distribution pattern for each fish species separately is explained with their spatial and temporal distribution. Month-wise occurrence of fishes in the study area
grid
is mapped on a gridded map showing their location in the area. These maps are an outcome of exhaustive GIS analysis of the fishery data to be represented in the darker to lighter shades on the map. Lighter to darker shades representing the quantity of fish catch in increasing order.

Zone-wise monthly representations of fishes are made and inter-species relationship, dominance and random patterns are explained in brief. Fish-wise monthly location maps and annual distribution pattern map for each fish species are shown in the study area.

The basic statistical technique i.e. used for determining spatial scales present study is explained with the help of formula used for semi-variance calculations.

A grammatically incorrect sentence?

Methodology for preparation of remote sensing data and preparation of data for variogram analysis has been explained. Schematic sketch representing various steps involved in variogram analysis along with figures on composites of transects and variograms are given. Through Dbase software, tables were derived from spatial scales and features and fronts were identified from the output graphs or variograms. An interpretation key was developed for variogram to obtain information as latitude, longitude, size , nearness to coast, variance difference for each feature and front for every variogram was done. Classification of spatial scales is done, into large, medium and small scales. It is supported by a number of Dbase tables. Satellite images of the study area are also presented.

Fish resources data present in the form of interpolated grid files were overlayed over each other to form groups of different categories based on their distribution and availability in the region. The seven groups thus formed are classified into very scarce, scarce, unizonal, bizonal, quadrizonal, well distributed and very well distributed. These categories showed a combination of fish species which shared almost common areas or habitats. These zones were compared and checked for the presence of any front or feature in it. The results are classified in terms of size, nearness to coast and amount of variance within their spread.

Zone-wise classification of all the fishes were done and grouped into seven categories. Each zone explains the various fishes found in them and the geographical location of these fishes. Variograms were drawn for forty transects separately for different latitudes extracted from the satellite data for the study area. Various fronts and features picked from the variograms and subsequent analysis were classified into three different classes i.e. strong, medium and weak fronts. A frontal map was drawn for all these fronts and each of these three categories of fronts were explained. Strong, medium and weak fronts were categorised in a semi-variance range between> 200 and <500 , between >100 and <200 and between 0 to 100. Each category showed different fronts in terms of their size, nearness to coast and locations.

Finally, twenty nine fish species taken up for the studies were classified into three frontal categories and their presence in strong, medium and weak fronts confirmed.

Major findings of the present work are:

1. Detection of frontal zones from synoptic satellite data, irrespective of spectral discrimination.

2. Technique of simultaneous analysis of satellite data and fishery distribution.

3. Technique of superimposition of fishery data on satellite data in raster and vector formats by way of format harmonization.

4. Relationship of frontal zones to fishery density and distribution.

5. A fishery related satellite based GIS technique which can be used as an alternative or supplementary mode to other existing methods of satellite oceanography.

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ALIGARH (INDIA)

DEDICATED TO

My Dearest

Loving Parents

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Internal : 300 / 301

DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY
ALIGARH-202 002
INDIA

Sections :
1. ENTOMOLOGY
2. PARASITOLOGY
3. ICHTHYOLOGY & FISHERIES
4. AGRICULTURAL NEMATOLOGY
5. GENETICS

Ref No.

Date

August, 1996

This is to certify that the work entitled, ***"Studies on coastal zone fishery resource potential using remote sensing and geographical information system techniques,"*** is completed by ***Mr Monowar Alam Khalid***. The work is original and independently persued by the candidate. The study is based on exhaustive and intensive data collection and analysis in Bay of Bengal and is aimed towards a new concept of assessing fishery resources in coastal zone.

The candidate is permitted to submit the work for the award of degree of ***Doctor of Philosophy*** in ***Zoology*** of the ***Aligarh Muslim University, Aligarh, India***.

(A.K. Jafri)
Ph.D; F.N.A.Sc.
Professor

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(Monowar Alam Khalid)

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CHAPTER ONE

INTRODUCTION AND REVIEW OF LITERATURE

1. GENERAL INTRODUCTION

Coastal zone is a dynamic environment where its waters are strongly influenced by various factors like local topography, wave and wind condition, variation in sea depth and the shape of the coastline,etc. Various waterbodies like estuaries and lagoons which are distributed in coastal zone are influenced by tidal action of the adjacent sea, as well as local inputs of freshwater. It is difficult to make scientific generalisation about coastal environment from observations made in particular localities because of the dominance of unique local conditions. Few workers like Krumbein (1961) and Whitten (1964) have recognised the complexity in its form and functions, but no unified definition has ever been attempted by any investigator.

~~Inspite~~ of the difficulty to address the coastal environment with a unified approach, it has been possible to view at it synoptically (Sudarshana, 1988). Though synopsis cannot be viewed as an alternate to totality, it can be considered very much nearer to reality in terms of space and time. So far, no remarkable attempt has been made to study the coastal processes by synoptic study. Dyer (1973) and Officer (1976) have contributions on coastal processes in estuaries and coastal seas, but they have devoted much of their attention to case studies of particular regions emphasising broad general principles. Few workers have attempted to describe the bio-optical state of the coastal waters through Satellite Remote Sensing. Gorden and Morel (1983) have classified coastal zone as Case-2 waters because of the dominance of high sediment load and high content of terrigenous yellow substances, whereas, in Case-1 water of the open sea, phytoplankton and their by-products play the dominant role.

Pressures on coastal zones caused by human population growth, maritime trade and offshore oil and gas exploration puts it at high risk of accidents and environmental damage. This calls for the synoptic information about the coastal ecosystem for which satellite synchronous experiments are the pre-requisites.

India has an impressive coastline of 7500 km, yielding about 2.5 million tons of fishes and supports aquaculture to the extent of 0.02 million tons. This vast extent of coastline is the genesis for the use of remote sensing in consideration of the synopticity in coastal investigations. Remote Sensing is preferred for its ease in spatial and temporal sequencing and its possibility of investigating an environment without visiting it. Geographical information system (GIS) is a technique to handle large amount of data generated by satellite remote sensing.

1.1 Coastal Zone

The coasts of the world's continents are the areas where the land meets the sea. The coast includes cliffs, dunes, beaches and sometimes the hills and plains that form the edge of the land. Coast can be generally described as t or has been affected by marine processes su currents and waves. The term Coastal zone includes the open coast as well as the bays and estuaries found in coastal indentations, it incorporates both land and water areas.

wrong syntax?

Though the term 'Coastal Zone' is extensively used in the literature, there remains considerable differences in opinions regarding its exact meaning (Hails, 1977). The resource agency of California refers 'Coastal zone' as the area extending inland approximately half mile from the mean low tide and seaward to the outermost limit of the state boundaries. According to Hails (1977), coastal zone is an area of variable width, which extends seaward to the edge of the continental shelf, but which has no distinct landward demarcation.

Sahai (1985) emphasized that with our limited land resources, fast growing population, the importance of resource management in the Indian coastal region cannot be over-emphasized. Roughly 25% of Indian population lives in coastal areas within 100 kilometers of coastline whose everyday life is greatly influenced by the interaction of land and sea.

1.2 Fishery

Fishery production in the Indian ocean is very low compared to that of any other major ocean. Forty percent of India's fish landings is contributed by the Indian ocean. When viewed against the world production of 90 million tons, India's contri bution is little over 2% (Khalid, 1993).

After the declaration of Exclusive Eco
(Fig. 1.1) of 200 nautical miles around our
approx. 2.02 sq. km) in 1977 (under the United Nations Laws of the Sea) for exploration, identification, exploitation and utilisation of marine resources, concerted efforts were made through sophistication in fishing trawlers with capabilities to conduct survey of resources distributed in the surface-waters (pelagic), mid-water (columnar) and at or near the ocean floor (demersal).

India, with a continental shelf of 0.5 million square km has a resource potential of 3.92 Million tons (Sudarshan *et al*, 1990). Marine fish production alone in 1991-92 was 24.69 lakh tons as compared to 23.00 lakh tons in 1990-91. Marine fish production pattern in 1990 was 45.06% for pelagic fish, 41.39% for demersal fish, 12.10 % for crustaceans and 1.45% for cephalopods. The share of marine products to export of agriculture products was 26% and to total national export was 3% (Department of Agriculture and Cooperation, Government of India). India earned 2980.99 crore rupees as total value of its marine fish production in 1990, showing a production of 22,20,173 tonnes.

1.3 Estimates Of Fishery Potential In Indian Exclusive Economic Zone (EEZ)

Several estimates have been made of the fishery resource potential as annual Maximum Sustainable Yield (MSY) from the

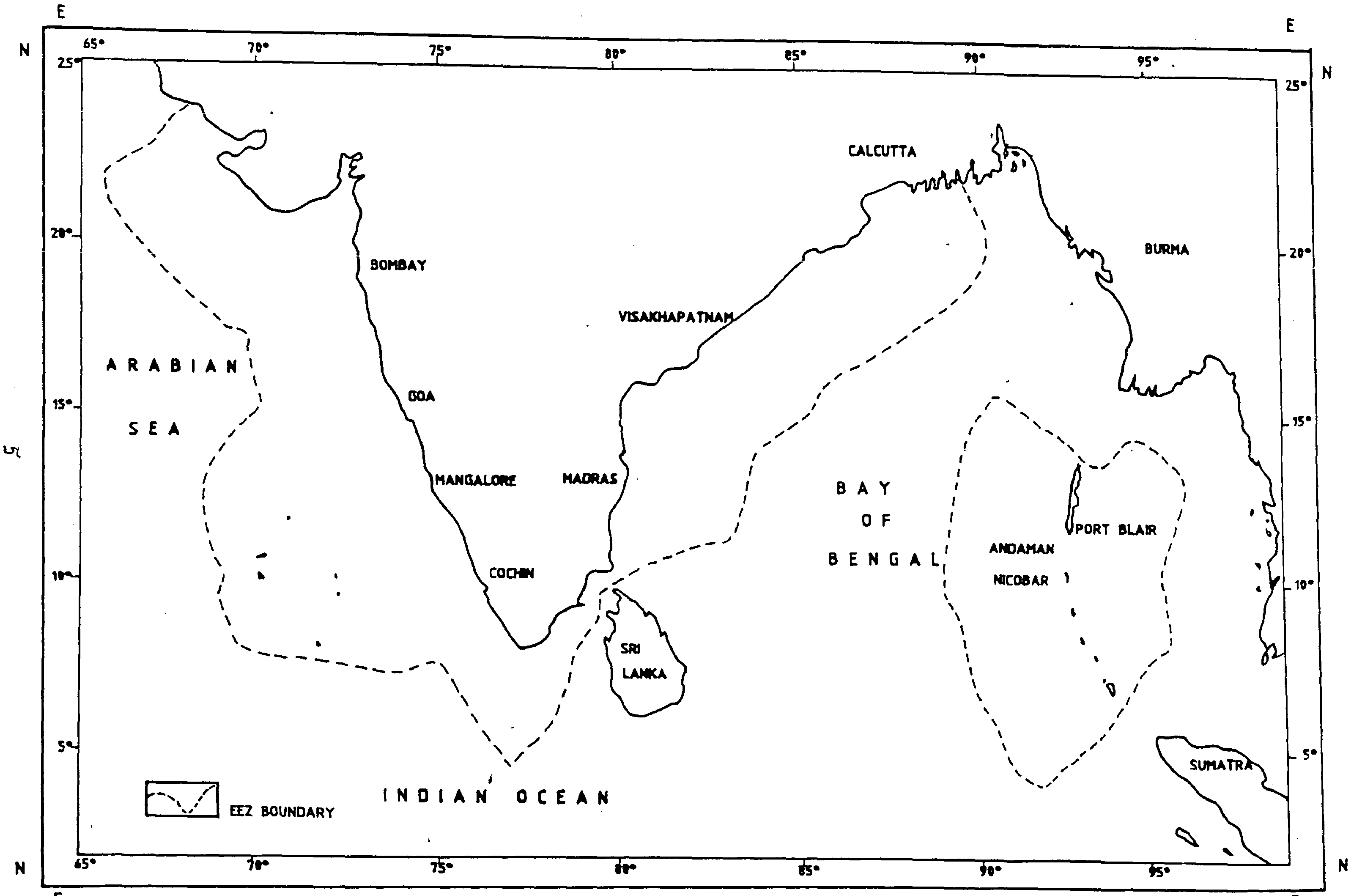


Fig. 1.1 INDIAN COASTLINE WITH ITS EXCLUSIVE ECONOMIC ZONE (EEZ).

5

Indian Exclusive Economic Zone (EEZ) based on the primary productivity studies, exploratory surveys and other parameters (Jones and Banerjee, 1973; Mitra, 1973; George *et al.*,1977; Nair and Gopinathan, 1981; Joseph, 1985, 1987; Sudarshan *et al.*, 1988; Alagaraja, 1989; Desai *et al.*, 1990; Mathew *et al.*, 1990). These estimates range from 3 to 5.5 million tonnes (Table 1.1) for the EEZ up to 200 nautical miles from the coast. The most direct among the estimates are those based on exploratory surveys in case of demersal resources and acoustic surveys coupled with test fishing in the case of small pelagics. Joseph (1980, 1987) made estimates of demersal resources up to 40 fathoms(73m) depth based on exploratory surveys and demersal and pelagic resources combined for the areas between 0-200m and 200-500m depth. Sudarshan *et al.* (1988) assessed the demersal resources along the Indian coast in 50-300m depth on the basis of exploratory surveys. The details of assessments based on the survey data generated by Fishery Survey of India (FSI) are furnished in Table 1.2.

1.3.1 DEMERSAL FISHERY RESOURCES

Demersal fishery resource assessments based mainly on the exploratory surveys are those of Joseph (1974; 1980; 1985; 1987), Joseph *et al.*(1976 a, b; 1987), Sudarshan (1987), Sudarshan *et al.* (1987, 1988) and Sivaprakasham (1986). These assessments indicate the annual potential of demersal stocks from areas within 70m depth along mainland as 1.7 million tons, around Andamans as 22.5 million tons, and from 50-300m depth around the mainland as about 0.55 lakh tons. Some estimates of potential

Table 1.1 Marine fishery resources potential in the Indian EEZ - Some estimates.

('000 tonnes)

Author	George et al. (1977)	Nair & Gopinathan (1981)	Joseph (1987)	Sudarsan et al. (1988)	Alagaraja (1989)	Sudarsan et al. (1989)	Desai et al. (1990)	Mathew et al. (1990)
Depth zone (m) / Region	0-200m and oceanic*	EEZ	0-500m and oceanic*	50-300/500m (Demersal only)	0-200m	Oceanic**	EEZ	EEZ
North west coast	883	5500	1620	460	1050	9	3660	2390
South west coast	1422		853		900	25		
Lower east coast	674		425	94	750	3		660
Upper east coast	735		531		300	6		
U.T. of Lakshadweep	90		90					
U.T. of Andaman & Nicobar	160		160			5		690
*Oceanic	500		500					
TOTAL	4464	5500	4179	554	3000	48	3660	3740

** Only deep swimming tunas, bill fishes and sharks

Source: Sudarshan et al.,1990

Table 1.2 Estimates of marine fishery potential in the Indian EEZ based on FSI database

Author	Resource	Potential yield estimate ('000 tonnes) North west coast	South west coast	Wadge Bank	Gulf of Mannar	Lower east coast	Upper east coast	Andaman Sea	Total
Joseph, 1974	Demersal (0-40fm)	231							
Joseph et al., 1976a	Demersal (0-40fm)		124						
Joseph et al., 1976b	Demersal (0-40fm)					75	131	-	
Joseph, 1980	Demersal (0-75m)	699	377			231	372		1679
Joseph, 1985	Demersal (0-200m)	928	438			243	416		2025
Joseph, 1987	Demersal (0-500m)	1124	331*			228	239	21	1943
Joseph et al., 1987	Demersal (10-100fm)			19					
Sivaprakasam, 1986	Demersal (20-200m)			27	17				
Sudarsan, 1978	Demersal (in shelf area)							45**	
Sudarsan et al., 1987	Demersal (0-500m)		240						
Sudarsan et al., 1988	Demersal (50-500m)		440	20	6	88			554
Sudarsan et al.; 1989	Oceanic tuna and allied species (EEZ)	9	25			3	6	5	48

* Including 27000 tonnes from Lakshadweep

**Standing stock

Source: Sudarshan et al.,1990

yield of demersal resources are presented in Table 1.3.

Of the total potential yield of 649.4 thousand tons, thread fin breams (110.6 thousand tons), horse mackerels (66 thousand tons), catfishes (63.4 thousand tons), mackerels (62.2 thousand tons) and bull's eye (54.8 thousand tons) form the first five main constituents of the finfish stock (Table 1.4). The other significant resources are scads, ribbon fishes, lizard fishes, squids and cuttle fish, sciaenids, carangids and perches.

1.3.2 COASTAL PELAGIC RESOURCES

The pelagic resources contributed on an average 47.3% to the total marine fish landings in the country between 1981 and March 1990. The current exploitation of pelagic stocks is mostly confined to the coastal belt.

Various estimates put-forth by various authors for pelagic resource potential varies between 0.6 to 2.46 million tons. George *et al.*, (1977) estimated 2.0 million tons, of which the potential from 50-200m depth around the mainland was placed at 0.7 million tons. Joseph (1987) assessed the total potential of pelagic resources at 1.7 million tons from 0-200m depth zone, of which 1.5 million tons is anticipated from the seas around the mainland.

The total potential yield of pelagic resources over the continental shelf is estimated to be 1.74 million tons (Table 1.5). About 63% of the estimated stock is on the west

Table 1.3 Some estimates of potential yield of demersal resources in Indian EEZ.

('000 tonnes)

Author	Jones & Banerjee (1973)	George et al. (1977)	Joseph (1987)		Sudarsan et al. (1988)		
Depth zone (m) / Region	0-200	0-200	0-200	200-500	50-100	100-200	200-300
West coast	577.0	1127.5	1378.0	50.0	315.2	102.6	22.0
East coast	143.0	867.5	434.0	33.0	55.9	28.9	3.4
Wadge Bank	-	-	-	-	6.8	12.1	0.7
Gulf of Mannar	-	-	-	-	1.7	4.4	0.2
U.T. of Andaman & Nicobar	4.0	20.0	21.0	-	-	-	-
U.T.of Lakshadweep	1.1	-	27.0	-	-	-	-
TOTAL	725.1	2015.0	1860.0	83.0	379.6	148.0	26.3

Source: Sudarshan et al.,1990

Table 1.4 Potential yield of demersal resources in 50-300/500m depth along the different regions of Indian coast as estimated from trawl surveys.

(in '000 tonnes)

Species/group \ Region	North west coast	South * west coast	Wadge Bank	Gulf of Mannar	Lower east coast	Upper east coast	Total
Threadfin breams (Nemipterus spp.)	71.7	25.0	10.1	0.3	0.4	3.1	110.6
Cat fishes	42.5	11.0	0.7	-	0.2	9.0	63.4
Sharks, skates and rays	10.5	0.8	0.5	0.2	0.1	0.9	13.0
Bulls eye (Priacanthus spp.)	25.5	18.2	0.5	0.2	3.4	7.0	54.8
Perches	9.9	1.2	1.3	0.5	0.3	1.4	14.6
Mackerels	9.0	2.5	-	-	0.9	49.8	62.2
Ribbon fishes	19.8	2.3	-	0.1	-	1.1	23.3
Squids & cuttle fishes	14.8	4.7	0.5	0.2	0.1	0.3	20.6
Horse mackerel	62.0	-	-	-	0.8	3.2	66.0
Scads (Decapterus spp.)	2.9	8.6	1.0	0.2	1.4	9.3	23.4
Trevally (Caranx spp.)	8.3	3.3	1.6	0.2	0.7	3.0	17.1
Ghol (Protonebea diacanthus)	3.5	-	-	-	-	0.6	4.1
Others sciaenids	14.6	0.1	-	-	0.1	3.1	17.9
Lizard fish	11.6	7.2	1.7	-	0.2	0.2	20.9
Pomfrets	10.0	-	-	-	-	2.0	12.0
Black ruff (Centrolophus niger)	-	7.7	-	-	0.8	0.8	9.3
Crabs	-	4.8	1.0	2.0	0.1	0.3	8.2
Indian drift fish (Ariomma indica)	-	1.6	0.6	0.2	0.7	4.0	7.1
Clupeids	6.2	-	-	-	0.6	7.5	14.3
Barracuda	0.8	-	-	1.2	-	1.2	3.2
Silver bellies	-	-	-	0.2	0.6	2.7	3.5
Deepsea prawns	-	3.1	-	-	0.1	0.1	3.3
Deepsea lobster	-	4.5	0.1	0.7	-	-	5.3
Others	55.4	5.7	1.0	0.6	1.0	7.6	71.3
TOTAL	379.0	112.3	20.6	6.8	12.5	118.2	649.4

* Upto 500m depth in lat. 8°-10°N along south west coast only

Source: Sudarshan et al.,1990

coast, 25% on the east coast, 4% in the Lakshadweep sea and 8% in the Andaman and Nicobar waters. By depth, about 57% of the stock is supported by the column over 0-50m depth zone.

The components of the pelagic resources as per the assessments are given in Table 1.6. Apart from the resources of oil sardine, mackerel, anchovies and Bombay duck, the major resources contributing to the pelagic fishery potential are the coastal tunas, ribbon fishes and carangids.

1.3.3 OCEANIC RESOURCES

Tuna, bill fishes, pelagic sharks, etc., constitute the main oceanic resource of the Indian ocean. Tuna fisheries in the Indian ocean account for about 10-12% of the world production of tunas. In view of the continuous and widespread distribution as well as the long range migratory habit of the larger tunas, assessment of likely stock size with EEZ has serious limitations. Dwivedi and Devaraj (1983) projected an assessment of standing stock of larger tunas in Indian EEZ as 6000 tons and maximum sustainable yield as 3000 tons. Silas and Pillai (1985) have indicated prospects for production of 210-225 thousand tons of tunas including skipjack from Indian EEZ. Sudarshan *et al.*(1989) estimated the potential of deep swimming tunas as 27,400 tons, bill fishes as 3800 tons, pelagic sharks as 15,800 tons and other species to be 1,200 tons.

Table 1.5 Potential yield of pelagic resources over the continental shelf (0-200m) along Indian coast.

('000 tonnes)

Depth zone	0-50m	50-100m	100-200m	Total
North west coast	331	161	27	519
South west coast	342	183	62	587
Lower east coast	213	32	29	274
Upper east coast	114	25	21	160
Lakshadweep				63
Andaman & Nicobar				139
TOTAL	1000	401	139	1742

Source: Sudarshan et al.,1990

Table 1.6 Estimated potential yield of different pelagic stocks over the continental shelf (0-200m) along Indian coast.

(in '000 tonnes)

Region	North west coast			South west coast			Lower east coast			Upper east coast			Lakshadweep*	Andaman & Nicobar*	Total
Species/group	0-50	50-200	Total	0-50	50-200	Total	0-50	50-200	Total	0-50	50-200	Total	0-200	0-200	
Mackerels	12	-	12	36	-	36	17	-	17	7	-	7	-	-	77
Oil sardine	11	-	11	160	-	160	6	-	6	4	-	4	-	-	181
Lesser sardines	10	-	10	24	-	24	49	-	49	8	-	8	-	10	101
Anchovies	33	-	33	21	-	21	18	-	18	7	-	7	-	1	80
Other clupeids	36	-	36	18	-	18	13	-	13	35	-	35	5	10	117
Bombay duck	115	-	115	-	-	-	-	-	-	17	-	17	-	-	132
Coastal tunas	3	11	14	11	67	78	6	10	16	1	4	5	50	100	263
Carangids	4	67	71	9	73	82	15	36	51	5	21	26	-	1	231
Seer fish	15	-	15	5	-	5	31	-	31	10	-	10	-	5	66
Ribbon fish	49	94	143	6	74	80	9	10	19	9	15	24	-	-	266
Pelagic sharks	1	15	16	2	29	31	1	4	5	1	5	6	-	5	63
Others	42	1	43	50	2	52	48	1	49	10	1	11	8	2	165
TOTAL	331	188	519	342	245	587	213	61	274	114	46	160	63	139	1742

* Adopted from Joseph, 1987

Source: Sudarshan et al.,1990

Among the oceanic squids, *Symplectoteuthis oualaniensis* and *Thysanoteuthis rhombus* are reported to be potential resources in Indian seas (Sreenivasan and Sarvesan, 1990). Silas (1986) has projected the potential harvest of oceanic squids from the Indian EEZ by 2000 AD in the order of 25-50 thousand tons.

1.4 Potential Yield Estimate Based On Organic Production

The fishery resource potential in the entire Indian ocean, based on organic productivity, has been assessed to be in the range of 7.8 to 16 million tons (Prasad *et al.*,1970; Moiseev, 1971; Prasad and Nair, 1973; Cushing, 1975; Qasim, 1977). Recently the potential yield from Indian EEZ alone was estimated as 5.5 million tons by Nair and Gopinathan (1981), 3.66 million tons by Desai *et al.* (1990) and 3.74 million tonnes by Mathew *et al.* (1990).

Sudarshan *et al.* (1990) gave the estimates of potential yield obtained with respect to the resources within 50m depth in the range of 0.2 to 0.6 million tons, which is much below the level of current production as well as estimates by direct methods.

The estimates of potential yield obtained for the area beyond 50m depth are in the range of 0.84 million tons to 2.52 million tons (Table 1.7). On combining this estimate of resource potential beyond 50m depth with the potential yield estimate of

Table 1.7 Estimates of potential yield of fishery resources beyond 50m depth in the Indian EEZ based on primary productivity studies.

('000 tonnes)

Region			West coast	East coast	Andaman & Nicobar	Total
Primary production (carbon/year)			81503	66821	62051	210375
Transfer coefficient*	0.1%	Fish standing stock	815	668	621	2104
		Potential yield	326	267	248	841
	0.2%	Fish standing stock	1630	1336	1241	4207
		Potential yield	650	535	496	1683
	0.3%	Fish standing stock	2445	2005	1861	6311
		Potential yield	978	802	744	2524
	** 0.1% to 0.5%	Fish standing stock	2088	1483	1735	5306
		Potential yield	835	593	694	2122

* Transfer coefficient from primary to tertiary productivity.

** Varying transfer coefficients (from primary to tertiary productivity applied depending on the level of primary productivity as below

Primary productivity (mg C/m^2/day)	100	100-200	200-400	400-600	600
Transfer coefficient	0.5%	0.4%	0.3%	0.2%	0.1%

Source: Sudarshan et al.,1990

2.28 million tons from within 50m depth, the total fishery potential in the Indian EEZ falls in the range of 3.12 to 4.80 million tons.

1.5 Fishery Surveys And Studies Performed

1.5.1 HISTORY

Since ancient times, seas have been used for transportation and communication. The successful global expedition of "H.M.S. CHALLENGER" of the United Kingdom during 1872-1876 opened doors for the oceanographic surveys. The success of the 'CHALLENGER' expedition stimulated the Royal Asiatic Society of Bengal to take initiative and establish the Marine Survey of India in 1874 to carry out work in Indian waters similar to that carried out by CHALLENGER. This expedition and subsequent exploratory works undertaken by the medical officers of the Royal Indian Navy, marked the beginning of oceanographic study in the Indian sub-continent. Colonel R.B.S. Sewell in 1910 took some observations on oceanography other than biological studies. Due to the first world war the work was temporarily suspended from 1914 to 1921, before it finally came to a stand still in 1926.

Later, useful oceanographic data were collected by research vessels which crossed the Indian ocean during the course of their global expeditions. These included the DANA EXPEDITION (1928-

30), JOHN MURRAY EXPEDITION (1933) and GALATHEA EXPEDITION (1950-52). As a result of these expeditions many interesting features of the Indian ocean became known.

After Independence, considerable resources were diverted towards the study of the oceans with the primary object to obtain more food from the sea. The investigations in the ocean science resulted in the accumulation of knowledge in the fields of marine biology and fisheries. With the setting up of Central Marine Fisheries Research Institute in 1947, the need for oceanographic investigations as an integral part of marine fisheries research was finally recognised.

Realising the importance of little understood phenomenon called 'monsoon' in the Indian ocean and its tremendous influence on the livelihood and economy of the countries bordering Indian ocean, the world community of oceanographers launched a cooperative investigation, the International Indian Ocean Expedition (IIOE). This was the first major cooperative investigation of the Inter-governmental Oceanographic Commission (IOC) of UNESCO, which was undertaken during the period 1960-65. India participated in this expedition from September 1962 to December 1965, with the vessels INS Kistna, R.V. Varuna, R.V. Conch and MFV Bangada. The Indian National Commission on Oceanic Research (INCOR) was established in 1962 by the Council of Scientific and Industrial Research (CSIR) to organise Indian participation in the IIOE. Fishery Survey of India (FSI), a nodal agency for exploratory sea surveys was established in 1946 and was called as Deep-sea fishing stations during 1946-74, its bases were known as off-shore fishing stations (1946-74). Later, it was known as Exploratory Fisheries Project in the years 1974-84. Since 1984, it is now known as Fishery Survey of India.

In 1962, an International centre, called the Indian Ocean Biological Centre (IOBC) was developed at Cochin with the help of UNESCO to provide facilities for zooplankton analysis during the expedition. The termination of IIOE saw birth of a new institution called National Institute of Oceanography (NIO) in 1966 under the Council of Scientific and Industrial Research (CSIR). Parallel developments also occurred in the Indian universities, which carried out investigations in the waters bordering India.

1.5.2 HYDROGRAPHY OF COASTAL WATERS

The hydrological features of the waters of Palk bay was explained by Murthy and Udayaverma (1964). Temperature and salinity structure of Bay of Bengal was studied by Murthy (1958). Murty and Ramasastry (1957) studied distribution of the density and the associated current at the sea surface in the Bay of Bengal. Murthy and Varadachari (1968) reported upwelling along the east coast of India.

Muthusamy (1974) investigated hydrography of the inshore waters of Madras for the period September 1976 to July 1970.

Naqvi *et al.* (1979) investigated the dissolved oxygen in the western Bay of Bengal. Neiman (1974) explained and observed some features of the Indian ocean surface current systems. Nathaniel (1985) investigated some bottom water oceanographic features in the Arabian sea. Biological and oceanographical differences between the Arabian sea and Bay of Bengal were observed by Panik kar and Jayaraman (1966). Parulekar and Ansari (1982) discussed benthic production and assessment of demersal fishery resources of Indian seas. Pati (1980) made observations on the hydrography and inshore plankton of the Bay of Bengal. Pati (1981) also explained the distribution and related ecology of pomfrets from the Indian seas. Patil and Ramamirtham (1963) studied the hydrography of the Laccadives offshore waters. Prasad (1985) explained wave climate and wave refraction along Madras coast.

Preliminary observations on the temperature gradients and light penetration in upper 200 feet of water in the Bay of Bengal were made by Prasad (1952). Oceanography of north Arabian sea was explained by Qasim (1982). Ragothaman and Rao (1978) reported diatom abundance in the nearshore waters of the Bay of Bengal. Distribution of dissolved silicate in the Arabian sea and Bay of Bengal was discussed by Rajendran *et al.* (1980). Ramamirtam and Jayaraman (1960) explained hydrological features of the continental shelf waters off Cochin. Ramana (1985) studied the variation of temperature, salinity in Arabian sea and attempted to study their possible influence on the oil sardine and mackerel fisheries in the area. Hydrography of the Kakinada Bay was studied by Ramasarma and Ganapati (1967). Surface water characteristics in the Bay of Bengal off Madras was observed by Ramasastry (1960). Ramasastry and Murthy (1957) carried out thermal field and ocean circulation studies along the east coast of India. Ramasastry and Maryland (1959) explained the distribution of density and associated currents at the sea surface in the Bay of Bengal.

Rao (1956) investigated the ocean currents of Visakhapatnam. Circulation and distribution of some hydrographical properties during winter in the Bay of Bengal were very well explained by Rao and Sastry (1981). Continental shelf waters along the east coast of India was observed by Rao *et al.* (1965). Studies on hydrography, phytoplankton and primary production off Waltair coast in Bay of Bengal was carried out by Rao (1967). Hydrographic features of the inner-shelf waters along central west coast of India for various seasons were studied by Rao *et al.* (1974). Upwelling and sinking along Visakhapatnam coast was observed by Rao *et al.* (1986). Rao and Rao (1974) reported distribution of dissolved organic phosphorus and nitrogen in the Bay of Bengal. Robinson (1966) explained the seasonal variation of temperature in the loom of the Indian ocean, Arabian sea, Bay of Bengal and Red sea. Report on nutrients of the North-western Bay of Bengal was given by Sankarnarayanan and Reddy (1968). Sasmal *et al.* (1986) reported monthly variations in some chemical characteristics of the near-shore waters along south Orissa coast. Subbaramayya and Ramamohan Rao (1986) observed variations of sea-surface temperature in Bay of Bengal.

Subrahmanyan and Gupta (1963) explained seasonal variations in the fat content of plankton and its relationship to phyto-plankters and fisheries by their studies on the plankton of the east coast of India. Varadachari (1958) performed meteorological and oceanographic studies of the coastal waters off Waltair in relation to upwelling and sinking. Observations on the process of upwelling and sinking on the east coast of India was made by Varadachari (1961).

1.6 Fisheries Of East Coast Of India

Studies on the fisheries of east coast of India were largely done by Fishery Survey of India and Central Marine Fisheries Research Institute. Biological productivity and estimates of fishery potential of the EEZ of India was done by Desai *et al.* (1990). Food and Agriculture Organisation (FAO) of United Nations (UN) in 1990 published a review of state of world fishery resources. Antony Raja (1986) gave the current knowledge of fisheries resources in the shelf area of the Bay of Bengal. Report on Orissa fisheries project was also given by Anthony Raja in 1986.

Joseph *et al.* (1976) gave the results of demersal fisheries resources survey along the east coast of India. An assessment of the demersal fishery resources off the Andhra-Orissa coast, based on exploratory trawling, was done by Krishnamoorthi (1976). Kuthalingam (1973) investigated the off-shore fishery resources of the Bay of Bengal from Sand-heads to Gopalpur. Phillipose *et al.* (1987) gave an appraisal of the marine fisheries of West Bengal. Marine fisheries of Orissa was studied by Roy (1981). Scariah *et al.* (1987) gave an appraisal of the marine fisheries of Orissa. Catfish resources of upper east coast of India was investigated by Sekharan (1973).

Sudarshan (1977) studied the prospects of prawn fishery off West Bengal. An appraisal of the marine fisheries resources of the Indian EEZ was given by Sudarshan *et al.* (1988). Sudarshan and Somvanshi (1988) studied fishery resources of Indian EEZ with special reference to upper east coast.

1.7 Data Analysis: Limitations Of The Conventional Studies

The data obtained from various surveys for fisheries exploration has certain limitations. Most of the coastal zone studies are confined to the easily accessible areas, using sample point techniques. Studies/data collection are performed without keeping in mind the synoptic view of the area. The data shows an average value of results in broad range. Data frequency and density is usually low. The geographic attributes are not well marked. Data is non-sequential, results are usually shown for whole area setting aside the geo-positional accuracy. There is no fixed distance between two stations i.e data stations on grid scale basis or in other words, there is a certain bit of randomness in the data collection.

1.8 Prospects Of Satellite Remote Sensing And Geographical Information System (GIS)

Oceans are vast and not easily accessible. It is difficult to survey ocean properties simultaneously and continuously at all places by vessels. Satellites can be of great help in covering larger areas of the oceans in very short time, thus making easier the monitoring of ocean parameters. The fast rate of data acquisition by satellite also make it convenient to use the data for prediction purposes.

Remote sensing application of coastal and marine resources is based on the synopticity that is obtained from satellite data. Monitoring of coastal waters require satellite data along with sea-truth (field) data to interpret the synoptic information. Remote sensing has proved effective both in terms of time and cost. Details on Remote sensing techniques and GIS principles are given in Chapter 2.

1.8.1 HISTORICAL PERSPECTIVE OF OCEAN REMOTE SENSING

The Seasat was the first satellite which was especially designed for ocean studies and was launched in 1978, but it failed to function after 100 days. Later, Seasat was replaced by

NIMBUS series of satellites which carried a visible wavelength Scanner (CZCS or coastal zone colour scanner) designed to observe ocean colour. In early 1986, French Satellite, SPOT was launched with a higher resolution (10m and 20m) sensor. This was followed by launching of Indian Remote Sensing Satellite IRS-1A on March 17, 1988. Microwave remote sensing to oceanography gained importance after the launch of ERS-1 satellite from European community.

Use of remote sensing applications for oceanographic purposes are relatively new in India. There is a scarcity of published literature/information on application of space technology for oceanographic studies in India. Therefore, a few published account of remote sensing applications to coastal/oceanographic studies relevant to the present theme of work is cited below.

Andrews (1983) applied remote sensing techniques to the marine environment. Armstrong (1983) studied the marine environment of Puerto Rico and the Virgin Islands through automated mapping and inventory using LANDSAT data. Bazigos *et al.*(1979) conducted aerial frame survey along the south-west coast of India in a United Nations Development Programme (UNDP)/FAO pelagic fishery investigation project.

Blindheim *et al.* (1979) conducted a survey of the coastal fish resources of SriLanka. Butler *et al.*(1986) wrote an introductory manual on marine resource mapping. Delineation of seasonal changes of chlorophyll frontal boundaries in mediterranean coastal waters with NIMBUS-7 coastal zone colour scanner data was done by Caraux *et al.*(1983). Cornillon (1986) prepared sea surface temperature charts for the southern New England fishing community. Cracknell (1983) published a detailed note on remote sensing applications in marine science and technology. Cram (1979) explained the role of the NIMBUS-9 coastal zone colour scanner in the management of a pelagic fishery. Hara (1985) explained moving direction of Japanese sardine school on the basis of aerial surveys. Allan (1983) explained that microwave satellites have an ability to resolve slicks, eddies, internal waves, bathymetric patterns, etc. Allan (1991) also explained that satellite sensors have been designed to measure surface roughness, colour, slope and temperature and stated that any ocean feature to be monitored from an orbiting satellite must produce a signature in one of these four parameters. Fukushima *et al.* (1993) studied average relative semi-variance on the coasts of Japan representing synoptic chlorophyll fields.

Holligan *et al.* (1983) performed satellite studies on the distribution of chlorophyll and dinoflagellate blooms in the western English Channel. Kemmerer (1980) explained environmental preferences and behaviour patterns of Gulf Manhaden inferred from fishing and remotely sensed data. Laskar *et al.*(1981) suggested the use of satellite infrared imagery for describing ocean processes in relation to spawning of the northern anchovy. Laurs *et al.*(1984) showed Albacore tuna catch distributions relative to environmental features observed from satellites.

Montgomery *et al.* (1986) explained the applications of satellite-derived ocean colour products to commercial fishing operations. Allan (1992) gave the application of various satellites for the marine environmental studies. Sudarshana *et al.* (1995) made some studies on relative semi-variance and dominant spatial scales in Japan.

Munday (1979) showed LANDSAT test of diffuse reflectance models for aquatic suspended solids measurement. Njoku (1985) attempted advances in sea surface temperature measurements and oceanographic applications. Coastal hydrography using the CCRS Lidar bathymeter was done by O'Neil (1983). Pringle and Duggan (1983) attempted a remote sensing technique for quantifying lobster fishing effort. Robinson (1985) gave a detailed account of satellite oceanography as an introduction for oceanographers and remote sensing Scientists. Roithmayr (1970) used airborne low-light sensor to detect luminescing fish schools at night. Stevenson *et al.* (1971) made some observations on remote sensing for fisheries.

Thomas (1980) explained coastal and marine applications of remote sensing. Venable (1984) studied sensitivity of airborne fluoro-sensor measurements to linear vertical gradients in chlorophyll concentration. Smith and Baker (1982) while using NIMBUS-7 CZCS data determined oceanic chlorophyll concentrations. Robinson (1983) reviewed the work of satellite observation of ocean colour. Robinson (1985) also dealt with an in-depth study of various aspects of problem of satellite oceanography.

Joseph and Somavanshi (1985) have highlighted the importance of a synoptic approach to Indian pelagic fishery in estimating our pelagic resources and in understanding various oceanographic processes which cause fluctuation in fish catches. Beena Kumari *et al.* (1985) carried out ground-truth data collection in the Arabian sea to arrive at diffuse attenuation coefficient which was directly proportional to phytoplankton pigment concentration. Narain *et al.* (1985) used airborne ocean colour radiometer and camera to target fish schools. Neera Chaturvedi *et al.* (1985) drew attention to an application of LANDSAT MSS data in ocean colour sensing. Dwivedi *et al.* (1985) while dealing with phyto-plankton pigment mapping from NIMBUS-7 CZCS data described the CZCS potential to give an idea of the limitation and applicability of this sensor. Dwivedi and Narain (1986) used LANDSAT TM data to retrieve the phytoplankton pigment off Azhikal in Arabian sea.

Sudarshan (1986a) stressed the need of application of remote sensing as an aid in marine biological studies. Sudarshana (1986b) experimented with LANDSAT MSS data for studies in shallow water benthic ecology of Karwar waters in Arabian sea. Subsequently, Sudarshana *et al.* (1988a) developed a model using time-series field data which was inter-related between physico-chemical parameters and spectral data. Sudarshana *et al.* (1988 b) further demonstrated application of remote sensing to marine fisheries using several satellite sensors. Beena kumari *et al.*

(1992) used NOAA-AVHRR temperature data to locate the tuna fishing grounds. The seasonal variability in fishery resources of Gujrat using NOAA data was reported by Solanki *et al.* (1992). Use of Indian Remote Sensing (IRS) satellite data in coastal aquaculture site selection was carried out by Siddiqui (1990) and estuarine studies in Zuari estuary, Goa, (India) by Khalid (1991).

Neera Chaturvedi *et al.* (1992) carried out some studies on seasonal changes in phytoplankton pigment and sea surface temperature (SST) and their relationship with fish catch using IRS-1A LISS-1 and NOAA-AVHRR data along coastal waters of Gujarat. Coastal zone resources support a wide ranging activities such as fishing, aquaculture, tourism, agriculture and marine commerce.

1.8.2 CONTEXT OF GEOGRAPHIC INFORMATION SYSTEM

Coastal zone fishery resource studies require a fast, precise and accurate methodological system for quick updation of events. Here comes the role of Geographical Information System (GIS), which comprises of a collection of integrated computer hardware and software which together are used for inputting, storing, analysing, manipulating and presenting geographical data (Fig. 1.2).

In other terms, function of a geo-referenced information system is to improve one's ability to make decisions on spatially existent themes having geographical coordinates. It is a chain

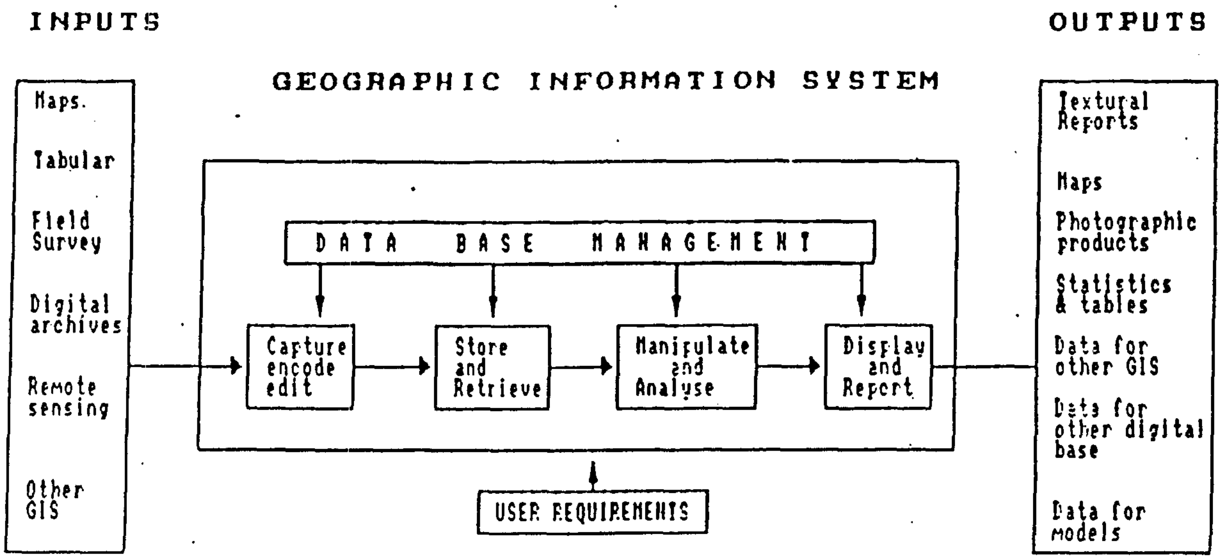


Fig. 1.2 Components of a GIS system.

of operations starting from planning the observation and collection of data, to store analysis of data and then to use the derived information in some decision making process. Meaden and Kapetsky (1991) studied the geomorphical information systems and remote sensing in inland fisheries and aquaculture. Khalid (1991) has done some preliminary studies in the information management of coastal estuarine systems in view of synoptic synthesis, which was attempted in Zuari estuary, Goa. Kapetsky *et al.* (1987) gave a geographic information system and satellite remote sensing plan for aquaculture development.

1.9 Scope Of Present Work

Present study makes an exhaustive explanation of fishery in an important coastal region of the sea and proposes an experimental approach for locating fish resources through identification of spatial scales of features from satellite data, since spatial scale of feature differ from environment to environment. Satellite derived spatial scale information can be used to help identify the physical processes affecting the biomass distribution such as currents, upwelling, temperature fronts and pollution, etc. Time-space variability at these scales have a direct impact on the growth and survival of planktons and fishes.

The area selected for the present study in north-west Bay of Bengal lies bet. 18°-20° N and 84°-89° E in the north-east coast of India. The study area covers around 11% of the total Indian coastline. The data for the present work has been constituted mainly from two sources, fishery surveys and Indian remote sensing satellite data.

1.9.1 FISHERY SURVEY DATA

Catch statistics for fishery resources was recorded in a haul-wise manner from fish catch data sheets prepared during the sea cruises of FSI vessels in 1990. Geographic entities like latitude and longitude for each haul was recorded accurately from satellite navigator present on-board ship. Data of nine months have been collected. Data for another three months could not be procured as vessel was either idle or was sailing in areas other than the study area.

1.9.2 SATELLITE DATA

The data of Indian Remote Sensing Satellite IRS-1B LISS-1 was used for the present study. The satellite data of IRS-1B LISS-1 (Path 19 Row 53; Path 19 Row 54; Path 20 Row 54; for three different seasons (averaged) was used to generally represent the time of data collection from field experiments) was procured in three high density digital tapes (HDDT or CCT) in blue, green, red and infra-red bands (between 0.4 to 1.1 wavelengths) from National Remote Sensing Agency (NRSA) of India.

Methodology followed for fishery data analysis is given elsewhere in this thesis (Fig. 3.4; Chapter 3). The data, after various transformations and processing was utilised for analysis of spatial scale of processes in fisheries environment. The heterogenity of the distribution of spatial scales of features is mainly dependent on ocean circulation and various other hydrodynamic processes, which affect the biological productivity. Atkinson *et al.* (1986) studied meso-scale hydrographic variability in the vicinity of Points Conception and Arguello. Bernstein and Chelton (1985) observed large-scale sea surface temperature variability from satellite and shipboard measurements. Halliwell and Cornillon (1989) observed large scale SST anomalies associated with sub-tropical fronts in the western northern Atlantic.

Rienecker and Mooers (1989) studied meso-scale eddies, jets and fronts of Point arena, California. Rienecker *et al.* (1987) studied dynamical interpolation and forecast of the evolution of meso-scale features off northern California. Yoder *et al.* (1987) studied spatial scales in CZCS-Chlorophyll imagery of the south-eastern U.S. continental shelf. Very recently, Khalid and Sudarshana (1994) attempted an analysis of shark fish resource across frontal boundaries in north-west Bay of Bengal from IRS satellite data using GIS technique. Govoni (1993) observed flux of larval fishes across frontal boundaries in Mississipi river plume.

The present work is the beginning of an understanding of coastal features and fronts as an aid to understanding the complexity of marine ecosystem. If technique of identification of spatial scales of features is found useful in prediction of fishery resources across fronts or features, it will be a great success in understanding the complex interplay of physical, chemical and biological factors of the sea.

1.10 Description Of Chapterisation

Chapter one deals with the general introduction about coastal zone fishery resources of India and various estimates of fishery potential in Indian EEZ for demersal, pelagic and oceanic fisheries. These are supported by the review of literature mainly of coastal waters and fisheries of east coast of India. Utility and prospects of Satellite Remote Sensing and GIS techniques are explained highlighting their advantages over conventional methods.

Chapter two explains the general principles of Remote Sensing and GIS techniques. They are explained in detail. Also, the use/scope of the remote sensing and GIS techniques for the present study has been explained.

Chapter three is about material and methodology used for the present study. After a general description of the study area, database used for the present study is explained. Methodology used for the study is explained in two phases. Phase-I explains transformations done to spatio-temporal fishery survey data and phase-II explains the transformations made to satellite data.

Chapter four explains the characteristics of fish distribution in an spatio-temporal trend. Twenty nine fish species are elaborately explained with their distribution pattern and in the form of image maps. Fish data is also explained zonewise showing some inter-species relationship, dominance and their random patterns. Annual distribution pattern maps for each fish species are also given.

Chapter five deals with the analysis of spatial scales of processes in the fisheries environment . Variogram analysis has been shown as basic statistical technique for determining the spatial scales of features by using semi-variance calculation formula. Methodology for deriving spatial scale of features/fronts and classification of spatial scales are also explained.

Chapter six gives the results and discussion for the present study. A detailed discussion on targetting fish resources potential are also explained. Fishes were grouped in seven categories and their presence in strong, medium and weak fronts were compared. The results are classified for fish availability based on frontal zones.

Chapter six is followed by summary and references.

CHAPTER TWO

GENERAL PRINCIPLES OF REMOTE SENSING AND GIS

2. REMOTE SENSING

2.1 Definition

Remote sensing is defined as a science of deriving information about an object by measurements made from a distance through a sensor, without actually coming in contact with it. Remote sensing is a multi-disciplinary tool for quick and efficient inventorying, monitoring and assessment of natural resources. Remote sensing involves collection and analysis of data done from remote platforms and serves as a tool for devising efficacious developments based on dynamic monitoring of our resources.

The term 'Remote Sensing' was coined in 1960 by Evelyn Pruitt of the United States Office of Naval Research. Remote sensing is more commonly used to identify earth features by detecting the characteristics of electromagnetic radiation that is reflected/emitted by the earth surface, Fig. 2.1 shows radiance components of the signal recorded by the satellite. Every object in the world reflects/scatters a portion of the electromagnetic energy incident on it depending upon its physical properties. Objects also emit radiation depending on their temperature and emissivity. If reflectance/emittance by an object is studied in different wavelengths, we get a reflectance/emittance pattern which is characteristic of that object known as "Spectral signature". Judicious interpretation of the spectral signatures lead to the identification of the features on the earth surface.

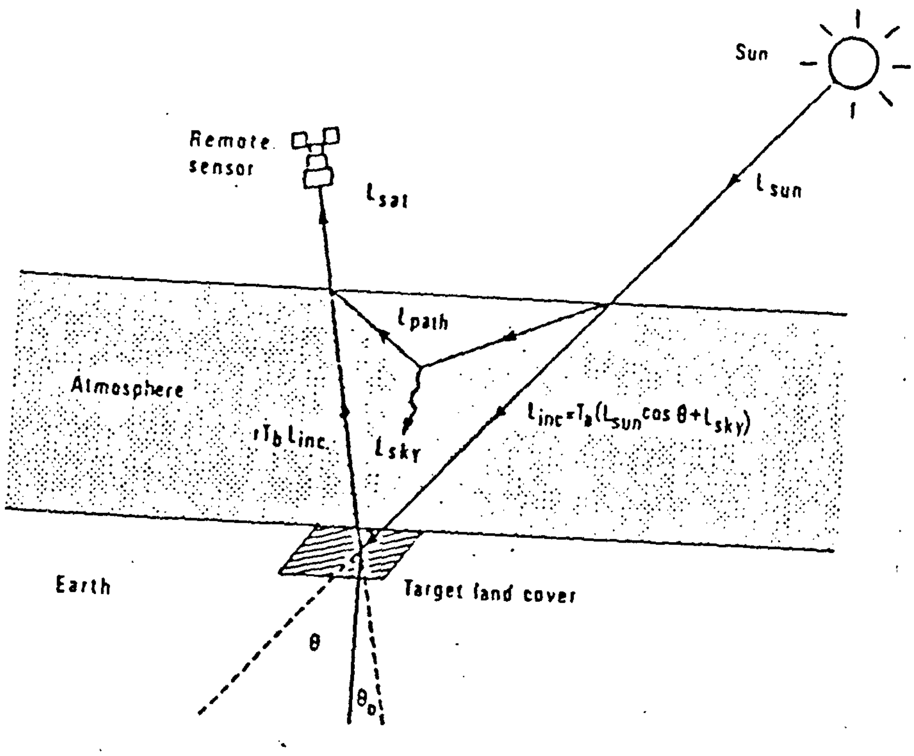


Fig. 2.1 Radiance components of the signal recorded by the satellite.

2.2 Electromagnetic Radiation

2.2.1 ELECTROMAGNETIC SPECTRUM (EM)

Electromagnetic spectrum (Fig. 2.2) is an array of a whole range of radiation that moves with the velocity of light, characterised by wavelength or frequency. The optical wavelengths (0.3 to 15 micrometer) are the ones most useful in remote sensing. Energy at these wavelengths can be reflected and refracted with solid materials like mirrors and lenses.

The region between 0.38 and 3.0 micrometer is termed as reflective portion of the spectrum as the energy sensed in these wavelengths is mainly due to reflectance of solar energy incident upon it. This is further divided into two parts - visible (0.38 to 0.72 micrometer) wavelengths and the reflective infra-red wavelength (0.72 to 3.0 micrometer). Electromagnetic energy in wavelengths from 7.0 to 15.0 micrometer is in far infra-red and called Thermal infra-red because of pre-dominantly emitted energy.

2.2.2 ATMOSPHERIC WINDOWS

The atmosphere of the earth has a degrading and impending effect on the solar radiation reaching the earth's surface, as the earth's atmosphere is transparent to electromagnetic radiations only in small parts. The spectral bands of least attenuation are called Windows. Important windows for remote sensing occur throughout the spectrum but the optical wavelengths extend-

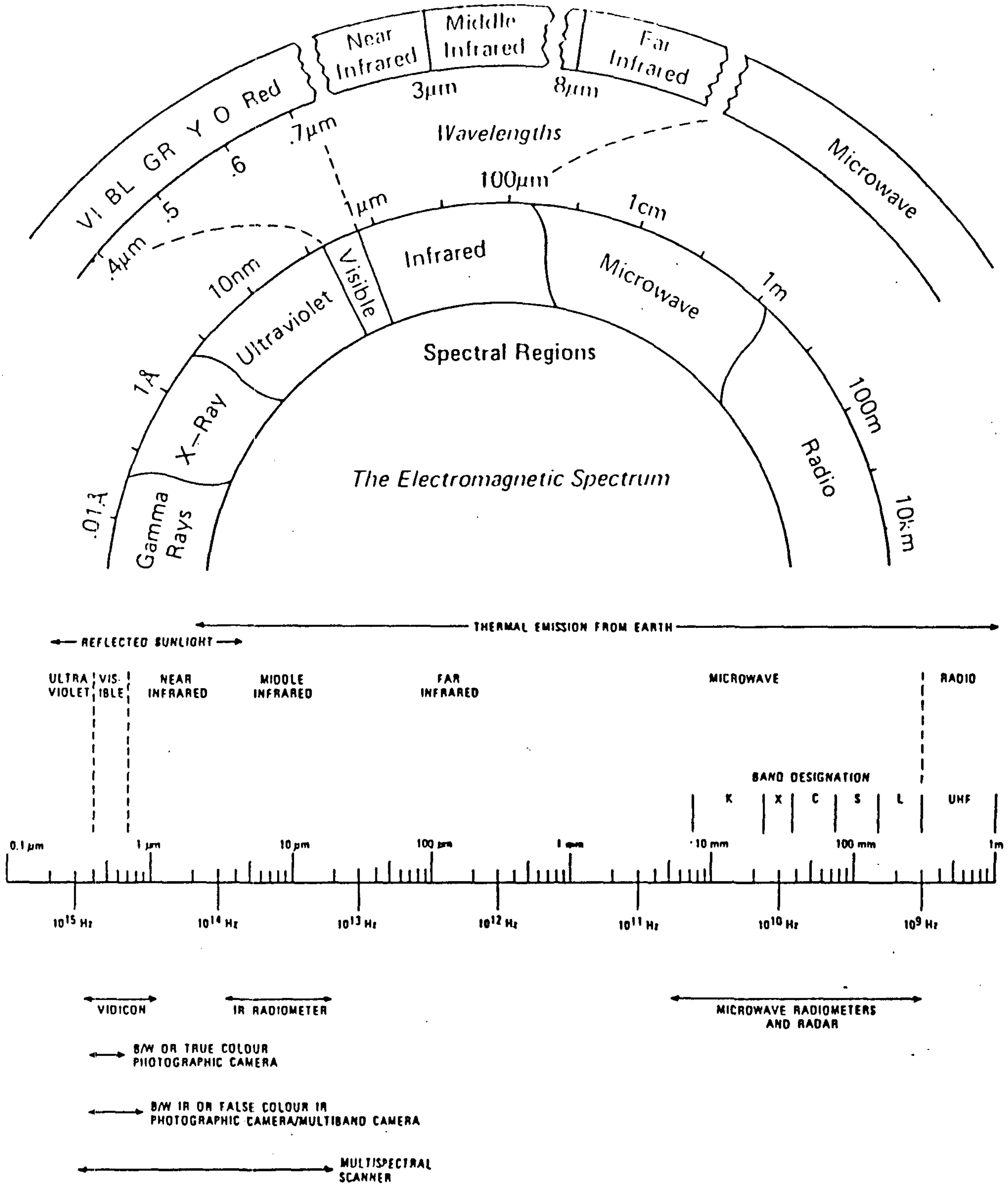


Fig. 2.2 Electromagnetic Spectrum

ing from 0.3 to 15.0 micrometers are of the greatest use in remote sensing. Important windows are as follows:

WAVELENGTH REGION	WINDOW	SENSORS
0.38-0.72	(i) 0.38-0.72	Camera & Multispectral
0.72-1.3	(i) 0.52-0.90	Camera & Multispectral
	(ii) 0.90-1.30	Multispectral Scanning
1.3-5.0	(i) 1.30-1.75	Multispectral Scanning
	(ii) 2.10-2.55	Multispectral Scanning
	(iii) 3.50-4.10	Thermal Scanning
	(iv) 4.40-5.00	Thermal Scanning
7.0-15.0	(i) 8.0-14.0	Thermal Scanning

2.3 Principles Of Remote Sensing

Detection and discrimination of objects or surface materials means detecting and recording of radiant energy reflected or emitted by objects or surface material. Different objects return different amount and kind of energy in different bands of electromagnetic spectrum, incident upon it. This unique property depends on the property of material (structural, chemical and physical), surface roughness, incidence, intensity and wavelength of the radiant energy.

Interaction of radiant energy is shown in Fig. 2.3. There are four major components of remote sensing.

1. Incoming energy source (natural eg. sunlight and artificial e.g. electromagnetic energy impulse).
2. Targets/objects/surface materials.

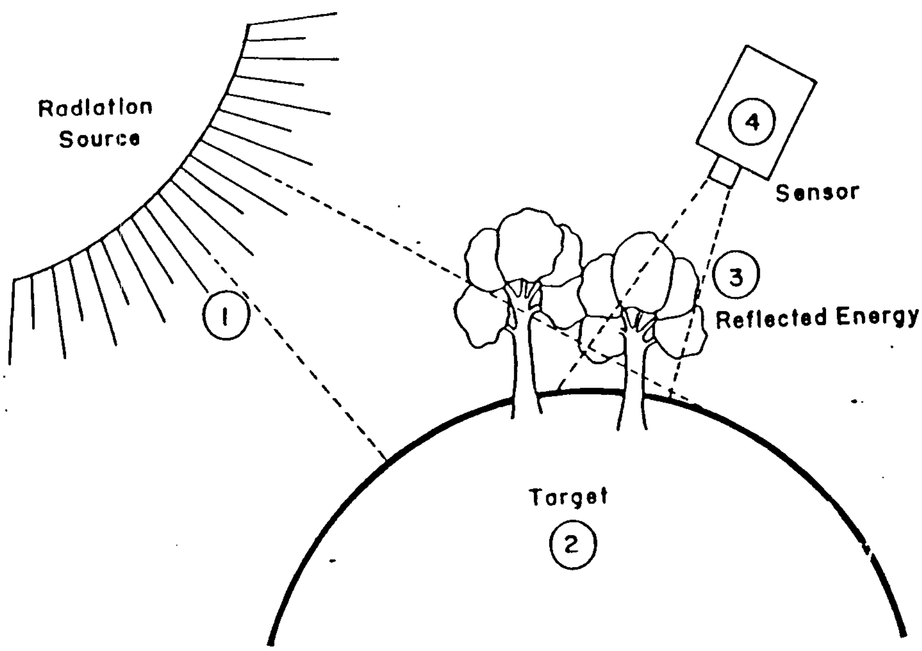


Fig. 2.3 Remote Sensing Model: Showing major components and their relationship.

3. Reflected energy.

4. Sensor/detector and recording system.

Remote sensing can either be active or passive. Active systems have their own source of energy whereas the passive system depends upon the solar illumination or self emission for remote sensing.

Sensor/Detector is the most important component of any remote sensing model. Sensor records the variation of radiant energy reflected or emitted by objects or surface material. Sensors sensitive to different parts of spectrum are now-a-days available. Spectral response of objects within the wavelength region 0.3 to 20.0 micrometer range is unique and can be used for identification or discrimination of objects just as signatures are used to discriminate different persons. Measurement of variation in spectral response enables identification and/or discrimination of different objects. Variation in spectral response can be due to either spectral variation (due to wavelength), spatial variation (due to shape, size, colour, location, etc.) and temporal variation (due to time) or combination of any of these factors. Detecting these differences enables identification of ground objects from sky. By dividing spectrum into number of bands and separately obtaining the responses there from, the uniqueness of spectral signature of any class of object can be further improved and a degree of confidence of recognition can be established. Thus, identification of materials/objects through remote sensing involves the following main steps:

(i) DATA ACQUISITION: Detection and measurement of variation in electromagnetic spectrum.

(ii) DATA INTERPRETATION AND ANALYSIS: Correlation of measurements and/or variations to know objects.

(iii) DERIVATION OF DESIRED INFORMATION: Extrapolation of information from known to unknown.

2.3.1 SPECTRAL RESPONSES

Spectral reflectance varies in its wavelength for different objects on earth. Fig. 2.4 shows the spectral reflectance curves for few selected features. Soil, water and vegetation are three important surface materials.

In case of soils, the reflectance depends upon number of factors such as colour, surface condition, moisture, organic matter and iron oxide,etc. In the case of water, there is a distinct decrease in reflectance from visible to infra-red wavelengths. This is observed both in clear and turbid waters. In the case of vegetation, low reflectance is observed in blue and red part of the visible spectrum due to chlorophyll absorption but the reflectance is high in green part.

In nature, however, these reflectance curves vary in many ways and for many reasons. For example, moist soil reflects differently than healthy vegetation, a crop on good soil appears

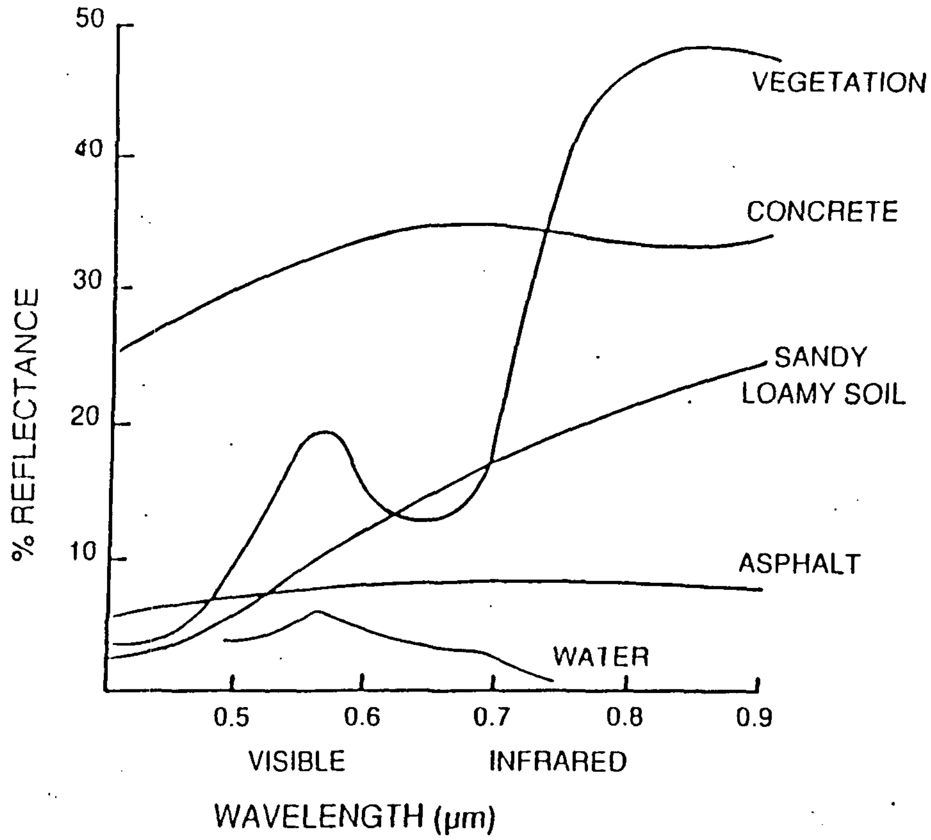


Fig. 2.4 Spectral reflectance curves for selected features.

differently from the same crop on poor soil, etc. Moreover the spectral response is not static but varies with time. Thus, it is imperative to understand physical and biological reasons for variations in reflectance for effective analysis of data.

2.3.2 MULTISPECTRAL APPROACH

Earlier, in Fig. 2.4, we have seen that spectral response varies with the wavelength and we can discriminate certain objects by acquiring spectral information in other parts of spectrum. If data is acquired in three different wavelengths, by plotting spectral responses in three dimensional space, objects similar in nature tend to form clusters which aid in their identification and discrimination from other objects. This is called multispectral approach and is found to be very useful in differentiating objects or surface materials which tend to have almost similar spectral response.

2.3.3 DATA ACQUISITION

The sensors are the most vital component of remote sensing data acquisition system. Sensors are of two types - image-forming and non-image forming.

Image forming systems are again of two types - framing and scanning types. In the framing type all the information is acquired simultaneously in the basic image unit e.g. in a frame such as photography. In the scanning type the information is acquired sequentially from the surface in bits of picture elements or pixels which may be arranged after acquisition into a frame format.

Non-Imaging type of sensors which are functions of time and spectral range are mostly used for ground observations and in the study of atmospheric and meteorological phenomena. These sensors do not form image and as such are not used in operational remote sensing but give detailed information on spectral characteristics of the target.

The basic techniques used in remote sensing data acquisition are:

1. Photographic system
2. Television systems
3. Multispectral and thermal scanning systems
4. RADAR and SAR

All these techniques have certain advantages and certain limitations. The limitations are imposed by certain factors such as :

(i) specific range of wavelength of electromagnetic spectrum used
(ii) variable geometry and image quality, and
(iii) variable resolution (spatial)

2.3.4 DATA PRE-PROCESSING

Aerial and satellite data contains geometric and radiometric errors which have to be corrected before the data is utilised for analysis and interpretation. Geometric errors are caused due to earth rotation, earth curvature, platform altitude and sensor flaws.

Radiometric errors are caused mainly due to non-uniformity in illumination of the objects and variations in sensor/detector response. In aerial photographs, these errors are not so serious due to the lower altitude of aircraft and relatively lesser velocity. However, satellite data needs to be extensively corrected and this is done using high speed computers, which are programmed for this purpose.

The corrected data is loaded onto computer compatible tapes (CCTs) which can be directly used for digitally analysing the data or the processed data. Data is converted from digital form into analog form using recorders in which photographic film is exposed. This film is then chemically processed to generate colour or black and white photographic products. These photo-imageries are then visually interpreted by the resource Scientists.

2.3.5 DATA ANALYSIS AND INTREPRETATION

Data analysis and interpretation is a very important step in remote sensing because sensor data gives a very limited information, and it is the interpretation and analysis of data that converts it into information.

To extract more information out of the raw data or to transform raw data into information that is usable, the remote sensing data has to be supported by ancillary data with ground information, knowledge of geographic area, etc., which are combined in data analysis and interpretation and are not recorded in remotely sensed data. Following are the main approaches of extracting information from the remote sensing data:

1. Image oriented or visual interpretation.
2. Numerical oriented or machine processing.

In the visual interpretation, photographic elements such as tone, texture, pattern, locations, etc., are used to extract the desired information. In the machine processing, the ground data collected in the field is fed into computer as samples and the whole scene is analysed through an interactive process on a sophisticated interactive system. It helps in categorising the whole scene into a number of classes depending upon the objective.

2.4 Advantages of Remote Sensing

Advantages of techniques of remote sensing for resorce surveys are:

1. Large area coverage or synoptic observation enabling regional surveys of variety of themes and identification of large features.

2. Repetitive coverage, allowing monitoring of dynamic themes like water, agriculture, etc.

3. Data acquisition over inaccessible areas.

4. Data acquisition at multiple heights - allowing different scales and resolution of data.

5. Same set of remote sensing data can be analysed/interpreted for different purposes and applications.

6. Amenability of remote sensing data to computer processing and thus making the method fast and accurate.

2.5 Description of Indian Remote Sensing Satellite IRS-1B and Its Applications

India became the fifth country in the world to have its own remote sensing satellite following the launch of its first indigenous satellite, Indian Remote Sensing Satellite (IRS)-1A, in 1988. IRS-1B was launched on 29th August 1991. The 915 kg IRS-1A and 1B are 3-axis stablilised spacecraft positioned in polar/sun synchronous orbit. In terms of configuration and capability IRS-1A and 1B are identical. IRS-1B has its main objective of derivation of data and is used for following applications:

1. Geological Applications

Regional geology and lineament studies, lithological mapping, alteration mapping, mineral targetting, oil exploration, uranium exploration, geo-morphological studies, etc.

2. Agriculture and Vegetation

Forest mapping, vegetation studies, crop and yield estimation, vegetation stress detection, etc.

3. Soil and Water Resources

Soil mapping, soil vegetation association, surface and ground water studies, snow and glacier mapping, snow melt estimation, reservoir studies, flood mapping, catchment and command-area surveys.

4. Environmental and Natural Disaster Management

Ocean studies, detection of oil films and industrial thermal plumes, landslides, erosion, deforestation, flood and earthquake hazards, monitoring volcanoes, forest fires and coal fires.

5. Landuse and Landcover Analysis

Landuse mapping, settlements, urban development and planning, integrated land resource surveys.

Fig. 2.5 shows an overview of IRS mission along with satellite characteristics and sensor system. The sensor payload

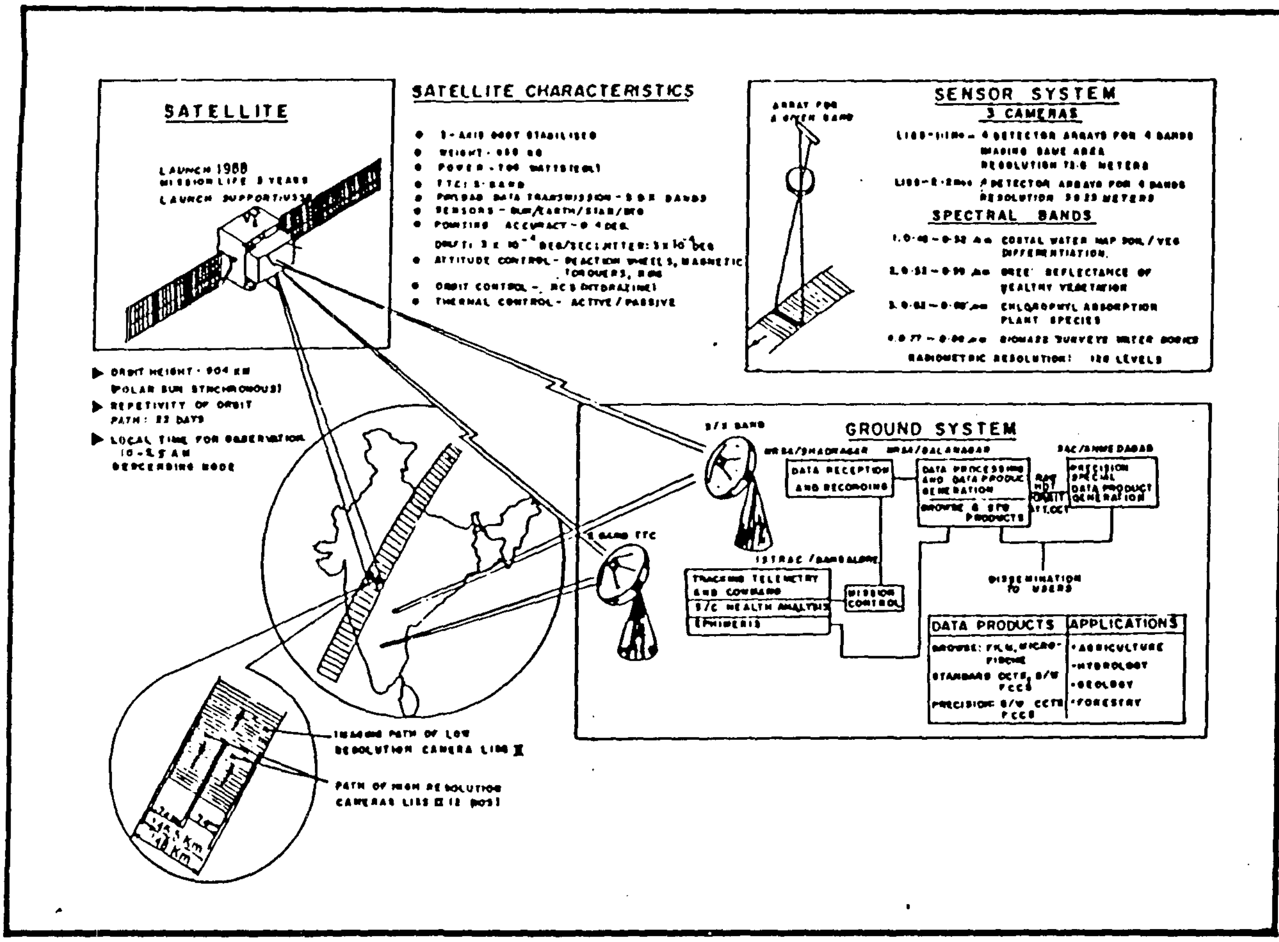


Fig. 2.5 An overview of IRS mission along with satellite characteristics.

of the spacecraft consists of two pushbroom cameras, Linear image self scanner (LISS-II) of 36.25m resolution and one camera (LISS-I) of 72.5m resolution employing linear charged couple devise (CCD) arrays as detectors. Each camera system images in four spectral bands in the visible and near infra-red region. The ground swath for the image obtained by the LISS-I camera is 148km. Whereas the LISS-II cameras image adjacent swath of 74km width each, with an overlap of 1.5km across track. The reflected energy sensed for each ground element/picture element (pixel) by the detector is quantized into 128 grey levels. India's acheivement in space programme is given in Table 2.1.

IRS-1B orbit details, payload system characteristics and its principal applications are as follows:

2.5.1 IRS-1B ORBIT DETAILS

Orbit	Circular Sun Synchronous
Altitude	904 km
Semi-major axis	7282.277 km
Inclination	99.028 degrees
Eccentricity	0.002
Period	103.192 minutes
Repetivity	22 days (307 orbit)
Orbits/day	14
Meantime of Equatorial crossing	10.25 AM (descending node)

Table 2.1 India's Achievement in Space Programme.

S.NO.	SATELLITE	DATE LAUNCHED	PURPOSE	LAUNCHER	RESULT
1	ARYABHATTA	19 April 1975	Scientific	VOSTOK	Success
2	BHASKER-1	07 June 1979	Earth Obs.	VOSTOK	Success
3	ROHINI	10 Aug 1979	__do__	SLV-3	Failure
4	ROHINI	July 1980	__do__	SLV-3	Success
5	ROHINI	31 May 1981	__do__	SLV-3	Success
6	APPLE	19 June 1981	Telecom.	ARIANE	Success
7	BHASKER-2	20 Nov 1981	Earth Obs.	VOSTOK	Success
8	INSAT-1A	April 1982	Multipurpose	DELTA	Success
9	ROHINI	17 April 1983	Scientific	SLV-3	Success
10	INSAT-1B	30 Aug 1983	Multipurpose	SHUTTLE	Success
11	SROSS-1	24 March 1987	Technical	ASLV	Failure
12	IRS-1A	17 March 1988	Rem.Sensing	VOSTOK	Success
13	SROSS-2	13 July 1988	Technical	ASLV	Failure
14	INSAT-1C	22 July 1988	Multipurpose	ARIANE	Failure
15	INSAT-1D	12 June 1990	Multipurpose	DELTA	Success
16	IRS-1B	29 Aug 1991	Rem.Sensing	VOSTOK	Success
17	SROSS-C	20 May 1992	Scientific	ASLV	Success
18	INSAT-2A	10 July 1992	Multipurpose	ARIANE	Success
19	INSAT-2B	23 July 1993	Multipurpose	ARIANE	Success
20	IRS-1E	20 Sept 1993	Rem.Sensing	PSLV	Failure
21	IRS-P2	15 Oct 1994	Rem.Sensing	PSLV	Success

2.5.2 PAYLOAD CHARACTERISTICS

	LISS-I	**LISS-II**
Focal length (mm)	162.2	324.4
Field of View (degree)	9.4	4.7+4.7
Instantaneous Field of View (micro rad)	80	40
Detector	2048 elements	2048 elem
Ground resolution (m)	72.5	36.25
Spectral range (micrometer)	0.45-0.86	0.45-0.86
Number of Bands	4	4
Swath (km)	148	74x2 (145 comp)
Radiometric resolution (grey lev)	128	128
Data rate (Mps)	5.2	10.4x2
Weight (kg)	38.5	80.8x2
Power (watts)	34	34x2

2.5.3 IRS SPECTRAL BANDS AND PRINCIPAL APPLICATIONS

BAND	**SPECTRAL RANGE** (um)	**APPLICATION AREAS**
1	0.45-0.52	- Coastal environmental studies (coastal morphology and sedimentation) - Soil/Vegetation differentiation - Coniferous/Deciduous vegetation discrimination
2	0.52-0.59	- Vegetation vigour - Rock/Soil discrimination - Turbidity/Bathymetry in shallow waters
3	0.62-0.68	- strong Chlorophyll absorption leading to discrimination of plant species
4	0.77-0.86	- Delineation of water features - Land forms/Geomorphic studies

IRS-1B is presently the fully operational indigenous remote sensing satellite. However, there are limitations in the application of IRS-1B data for oceanographic and marine biological studies. First is the collection of satellite data which is required to be synchronised with the collection of field data at the time of satellite pass. The second aspect of the limitation of the selection of wavelength bands which were originally designed for landuse studies. However, there is considerable scope to explore new and emerging applications to evaluate coastal resources.

2.6 Remote Sensing and Fishery

To exploit sea resources covering two third of the earth surface, reliable environmental information is required. Variations in environmental conditions affect the recruitment, distribution, abundance and availability of fishery resources. It is not possible to measure remotely the entire range of information needed to assess changes in the marine environment. Knowledge of particular conditions and processes affecting fish populations, however, may often be deduced using measurements made by remote sensors, e.g. concentration of dissolved and suspended matter, variations in primary production levels, distribution of surface isotherms, location of frontal boundaries, regions of upwelling, currents and water circulation patterns, etc. The parameters providing information on these environmental factors may allow a forecast of fish distribution or more generally the definition of marine fish habitats. Various satellites and their sensors used for marine studies are shown in Table 2.2 (Qasim, 1992).

2.6.1 FISHERY PARAMETERS DETECTED BY SATELLITE REMOTE SENSING

Most likely, fish responds to the sum total of environmental factors. Therefore, it becomes necessary to correlate a large number of parameters obtained by remote sensing techniques with fish distribution. Environmental parameters most commonly measured from spaceborne sensors are listed below, their studies help in indirect assessment of fishery.

A. Surface Optical Properties

The optical properties in the marine surface layer are determined by the presence of dissolved and suspended matters. Under normal conditions, visible light penetrates marine waters to a depth of tens of meters (Butler *et al.*,1988). As the concentration of the water constituents increases, i.e. the water becomes more turbid, the penetration of sunlight is reduced as a result of absorption and scattering processes. Depending on the specific characteristics of the materials present in the water, i.e. on their spectral signature, the absorption and scattering processes will vary with the wavelength of the incident radiation. Multispectral observations, therefore, can be employed to estimate the nature and concentration of the water constituents. The main parameters which can be derived remotely from water emergent radiation, through the use of empirically constructed

Table 2.2 Marine Satellites and their Sensors used for mapping-Past, Present.

SATELLITE AND STATUS	SENSORS	APPLICATIONS
SEASAT(Nop)	ALTIMETER SCATTEROMETER SMMR	Wind speed, Sea surface Temperature, Atmospheric water vapour, Wave height
NIMBUS(Nop)	SMMR, CZCS	Sea surface temperature, Wind speed, Fisheries, Pollution
GEOSAT(Nop)	ALTIMETER	Wind speed, Wave height
NOAA(Op)	AVHRR, TOVS, MSU	Sea surface temp., Vertical temp., Atmospheric water vapour Cloud & rainfall estimates
MOS(Op)	MESSR, VTIR, MSR	Fisheries, Marine pollution, Sea surface temp., Water vapour Suspended sediment
LANDSAT(Op)	TM	Coastal landuse, Sedimentation Chlorophyll mapping
SPOT(Op)	HRV	Coastal landuse, Sedimentation, Chlorophyll mapping
IRS(Op)	LISS I & II	Coastal landuse, Sedimentation, Chlorophyll mapping
ERS-1(Op)	SAR, SCATTERO-METER, RADAR ALTIMETER, SCANNING RAD-IOMETER, MICR-OWAVE SOUNDER	Pollution monitoring, Sea surface topography, Sea surf-ace temperature, Weather modelling

(Nop) = Non operational
(Op) = Operational

algorithms, are as listed below:

i. Diffuse Attenuation Coefficient

The diffuse attenuation coefficient at a specific wavelength is an apparent optical property. Its values can be interpreted as a measure of water turbidity and it constitutes a valuable tool in fisheries studies.

ii. Total Suspended Matter (Seston)

The utilisation of this parameter may be most appropriate when classifying waters, where inorganic or organic sediments make an important contribution to the optical properties of the surface layer. Sediment concentration can be used as a natural tracer for the identification of water movement and frontal boundaries.

iii. Yellow Substance

It is defined as material derived from the degradation of land and marine organic matter. It is an important parameter to monitor in the context of polluted coastal waters, since it may be used to identify marine areas where the exploitation of filter feeders, e.g. shellfish, could be hazardous.

iv. Chlorophyll Pigments

The concentration of chlorophyll pigments (the photosynthetic pigments of phytoplankton) is often considered as an index of biological productivity and, in an oceanic environment, it can be related to fish production. Chlorophyll concentrations above 0.2 mg/cu.m indicate the presence of sufficient planktonic life to sustain a viable commercial fishery (Gower, 1972).

v. Macrophytes

Macrophyte vegetation (seaweed) is commonly seen in coastal areas. Some species are of economic importance, but all the species play an important role in supporting marine life.

B. Sea Surface Temperature (SST)

The process of extracting SST information from IR radiometer data is well established (Njoku *et al.*, 1985; Roy, 1978; and Deekshatulu *et al.*, 1992). Global sea surface temperature charts are produced on an operational basis. They are in the form of computer print-outs or contour maps with spatially smooth and radiometrically corrected measurements. It has been possible with data derived from TIROS, NOAA and the METEOSAT satellites to produce SST charts with an accuracy of $0.5\text{-}2_{o}$ C and in near real time.

To date, SST maps are mainly used by the salmon and tuna fishing fleets. It is well known that some tuna species feed on the warm seaward side of thermal fronts while salmon feed on the cold landward side. The occurrence of some other species can also be correlated with SST. In addition, physical features such as gyres, eddies, inversions and upwelling which are of importance to fisheries can also be detected using SST maps.

C. Circulation Features

Circulation features are important in defining marine fish habitats. These include the location and evolution of frontal boundaries, upwelling area, currents and circulation patterns, etc. Optical and thermal characteristics of surface water can be used as natural tracers of dynamic patterns.

D. Salinity

On-going research indicates the possibility of determining salinity (Butler *et al.*, 1988) with the use of microwave sensors to an accuracy of one part per thousand. The emissivity of sea water is related to salinity. Changes in the salinity cause significant changes in the emissive brightness temperature of water for frequencies less than 5 Giga Hertzs. Hence the salinity of sea water can be determined remotely by measuring accurately the emissive brightness temperature. Technique can be used for mapping the spread of freshwater at a river mouth or for studying estuaries and near shore waters.

E. Oil Pollution

Oil detection at the sea surface is possible through various methods. Microwave detection by SMMR and SAR, thermal detection by IR scanner, etc.

Microwave method is based on the difference of emissivity between the sea surface and oil slick. Thermal sensors identify oil by means of the difference in solar absorption and thermal emissivity between oil and water and they also provide a basic measurement of oil thickness.

F. Sea State

It has been known for sometime that rough sea conditions created by wind have an effect on the distribution of fish. Synthetic aperture radar (SAR) equipped aircraft or satellites can survey the sea state of fishing grounds in near real time.

The microwave sensors on board SEASAT were capable of measuring the following with a high degree of accuracy:

(i) RADAR ALTIMETER: Wave height and the microtopography of the ocean surface.

(ii) SYNTHETIC APERTURE RADAR (SAR): Wavelength and direction.

(iii) RADAR SCATTEROMETER (SASS): Near surface wind speed over the oceans in all weather conditions.

2.7 Scope Of Remote Sensing In The Present Work

The present work is a new approach for locating the presence of fishes through identification of satellite derived spatial scales of features, as they differ from environment to environment. Chua (1991) formulated a process in identifying coastal area management (CAM) issue and formulated an integrated CAM plan (Fig. 2.6).

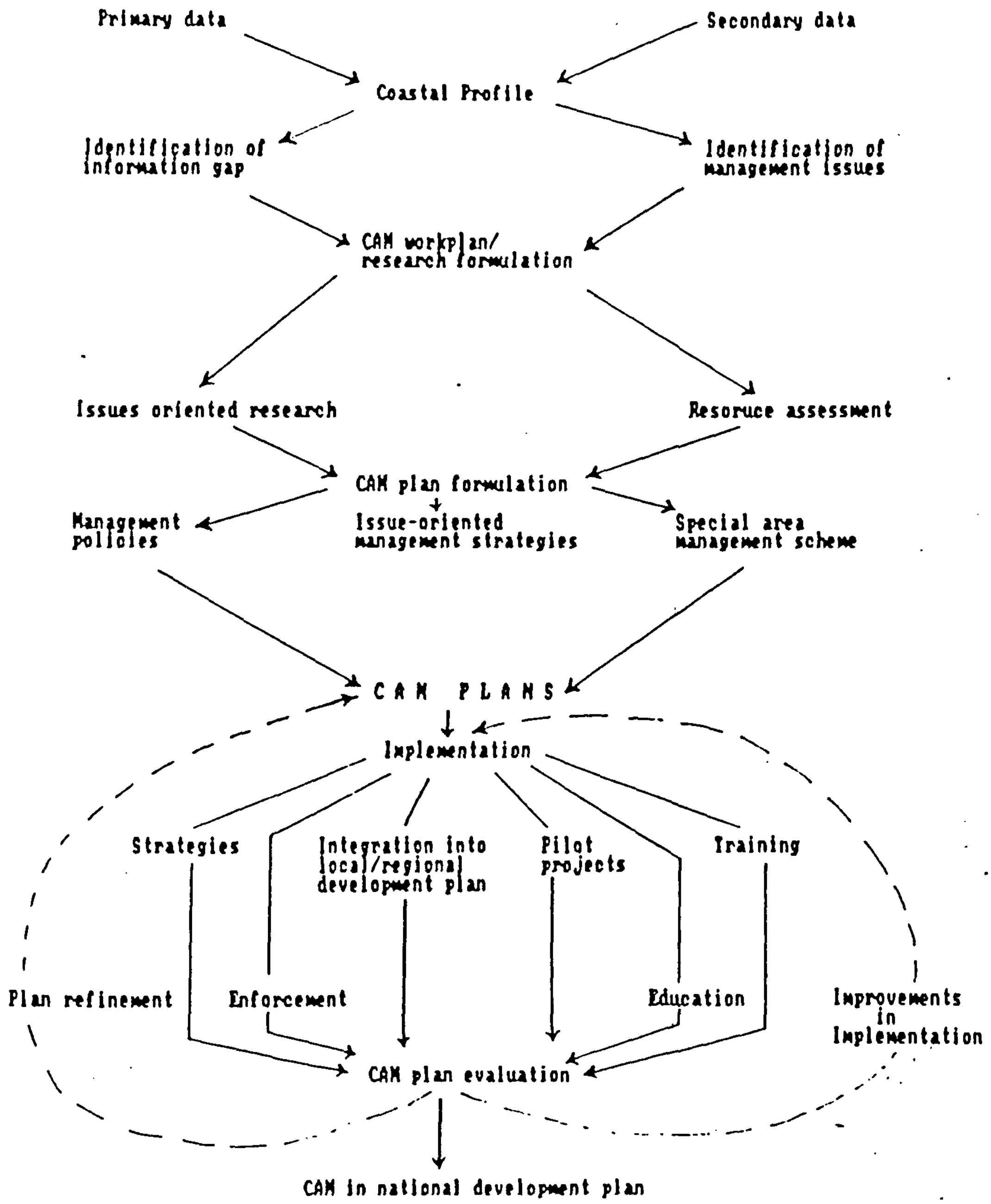


Fig. 2.6 Process in identifying coastal area management (CAM) issues and formulating integrated CAM plans . (Chua, 1991)

Remote sensing has a proven potential identifying the environment most suitable for fishes and locating their presence for better catches. IRS-1B LISS-I satellite data was applied for the first time in identifying coastal features and fronts in northwest Bay of Bengal. Khalid and Sudarshana (1994) made an attempt for locating the presence of sharks through identification of spatial scales of features from satellite data. Satellite derived spatial scale information can be used to help identify the physical processes affecting the biomass distribution such as currents, upwelling, temperature, fronts and pollution. Remote sensing satellite data gives time-space variability at these scales which help in ascertaining the effect on growth and survival of zooplankton, larva and adult fish. Various environmental polar orbiting satellite systems or programmes are shown in Table 2.3.

2.8 General Principles Of Geographical Information System (GIS)

The term Geographical Information System (GIS) is frequently applied to geographically oriented computer technology. The basic meaning of GIS as three different words are explained as follows:

- GEOGRAPHICAL : It contains data and concepts which are concerned with spatial distribution and denotes location of data.
- INFORMATION : It implies some notion of conveying data, ideas or analysis, usually as an aid to decision making.
- SYSTEM : It involves the sequence of inputs, process and outputs.

Table 2.3 Environmental Polar Orbiting Satellite Systems or Programmes.

Sl. No.	Satellite Programme	Country	Year of Launch	Operational State	Sensors carried
1	TIROS/NOAA Ist series	USA	1970-76	Ceased	AVHRR,AVCS
2	LANDSAT 1, 2,3	USA	1972-78	Ceased	MSS,RBV
3	METEOR	USSR	1977	Active	MSS,MRTVK
4	TIROS/NOAA 2nd series	USA	1978	Active	AVHRR
5	HCMM	USA	1978	Ceased	HCMR
6	NIMBUS-7	USA	1978	Ceased	CZCS,SMMR, LIMBS
7	SEASAT-a	USA	1978	Ceased	SMMR,RA,SASS, VIRR
8	BHASKAR series	INDIA	1979	Ceased	MW Radiometer
9	LANDSAT 4,5	USA	1982-84	Active	MSS,TM
10	KOSMOS	USSR	1983	Active	SLAR,MRIR, MRTVK cameras
11	SPOT 1,2	FRANCE	1986	Active	HRV
12	MOS 1a,b	JAPAN	1987-90	Active	MESSR,MSR,VTIR
13	IRS-II,IB	INDIA	1988	Active	LISS I & II
14	NROSS	USA	1989	Active	SCATTEROMETER
15	ERS-I	ESA	1991	Active	AMI,SAR,ATSR, RA,SCATTERO-METER
16	JERS-I	JAPAN	1991&97	Active	OPTICAL & MIC-ROWAVE SENSOR
17	LANDSAT-6	USA	1993	Failure	ATM
18	IRS-1C,ID	INDIA	1994-95	Planned	LISS-III,WiFS, PANCHROMATIC Camera
19	SEASTAR	USA	1994	Planned	SEAWiFS
20	SPOT 3,4	FRANCE	1994-95	Planned	IMPROVED HRV, VEGETATION MO-NITORING SENS-OR, RA
21	OCEANSAT	INDIA	1995-96	Planned	SAR,RA,SCATTE-ROMETER
22	LANDSAT-7	USA	1996	Planned	ATM,STEREO-MAPPER
23	COLUMBUS	ESA	1997	Planned	MERIS
24	JERS-2	JAPAN	1998	Planned	OPTICAL AND MICROWAVE SENSOR

The three strands mentioned above are given functionality within a recent technological scenario based on 'Hi-tech' capabilities.

2.8.1 DEFINITION OF GIS

GIS is defined as a computerised system which effectively stores, retrieves, manipulates, analyses and display the data according to user defined specifications.

Various definitions have been given by different authors for GIS. A few selected definitions are listed below :

PARKER (1988)

" An Information technology which stores, analyses and displays both spatial and non-spatial data."

DEUKER (1979)

" A special case of information systems where the database consists of observations on spatially distributed features, activities or events which are definable in space as points, lines or areas. A GIS manipulates data about these points, lines and areas to retrieve data for adhoc queries and analysis."

SMITH *et al.* (1987)

" A database system in which most of the data are spatially indexed and upon which a set of procedures operated in order to answer queries about spatial entities in the data base."

BURROUGH (1988)

" A powerful set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world."

COWEN (1988)

" A decision support system involving the integration of spatially referenced data in a problem-solving environment."

2.8.2 COMPONENTS OF GIS

GIS comprises of following main components (Fig. 2.7).

1. Main Hardware
2. Input
3. Main Software
4. Output

i. Main Hardware

Any physical devise used as a part of computer system to store, process and display constitutes the main hardware. Fig. 2.8 shows the main hardware components of GIS.

ii. Input

It is the data input in computer through maps, tabular data, field observations, remote sensing, etc. Various components of input data are shown in Fig. 2.9.

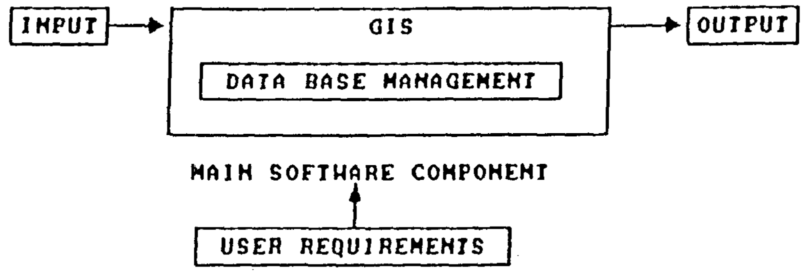


Fig. 2.7 Components of GIS.

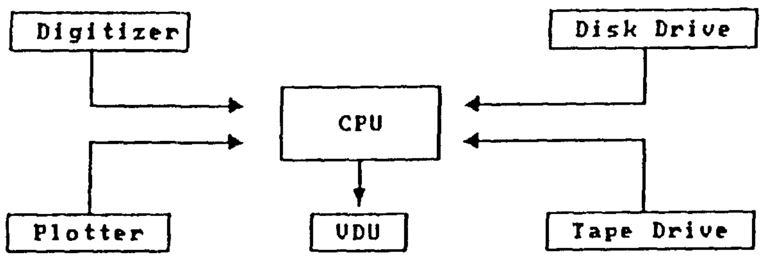


Fig. 2.8 Main Hardware Components of GIS.

iii. Main Software

These are a set of programmes used to perform tasks in a GIS. They are used to control and perform operations. There are a number of software packages available for database management in a GIS. Various software components are shown in Fig. 2.10.

iv. Output

Query oriented inputs in database management softwares yield results, these are displayed and reported in various forms (Fig. 2.11) or products called as outputs of GIS.

2.9 GIS And Its Relations With Other Information Systems

It is important to establish a definition of GIS by studying its relationship with other systems like computer cartography, database management systems (DBMS) and remote sensing information systems (RSIS). Fig. 2.12 explains the relationship of GIS with these systems.

2.9.1 COMPUTER AIDED DESIGN (CAD)

These systems were developed for designing and drafting new objects. They are graphic based and use symbols as primitives to represent features in the interactive design process. CAD systems have only rudimentary links to databases which typically might contain part listings or stock reference numbers. CAD systems do not allow users to defined criteria and have limited analytical capabilities.

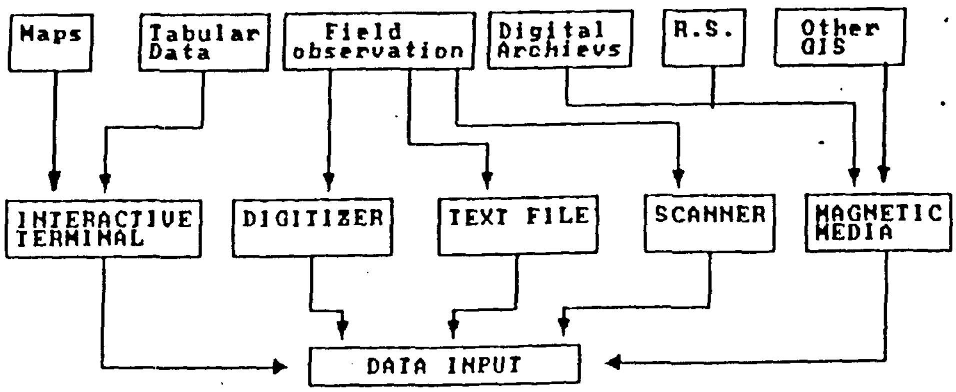


Fig. 2.9 Input in GIS

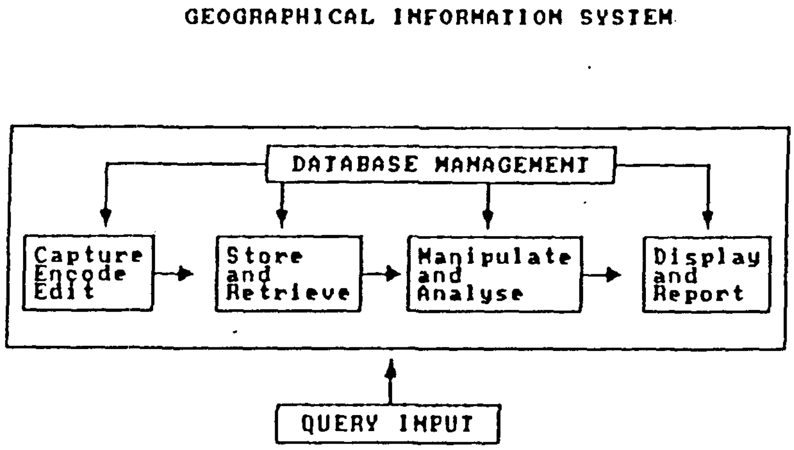


Fig. 2.10 Main Software Components.

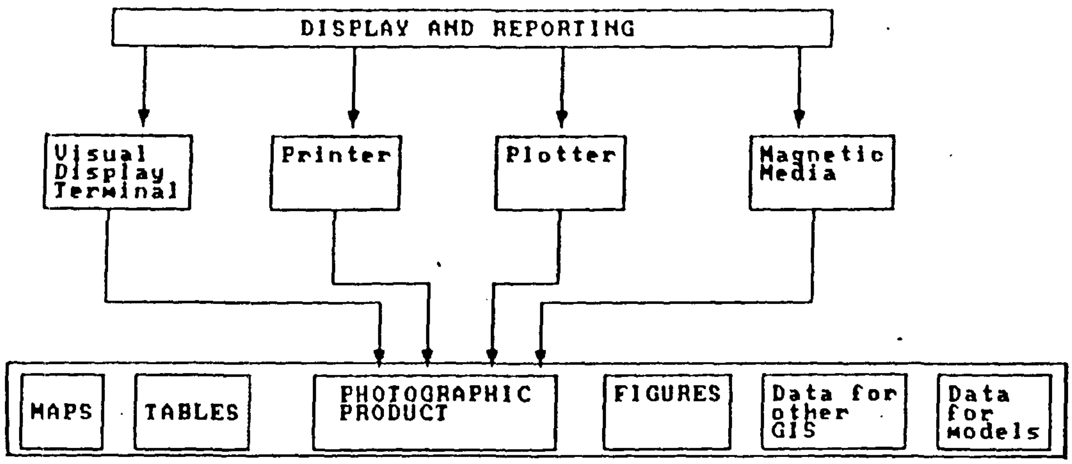


Fig. 2.11 Outputs of GIS.

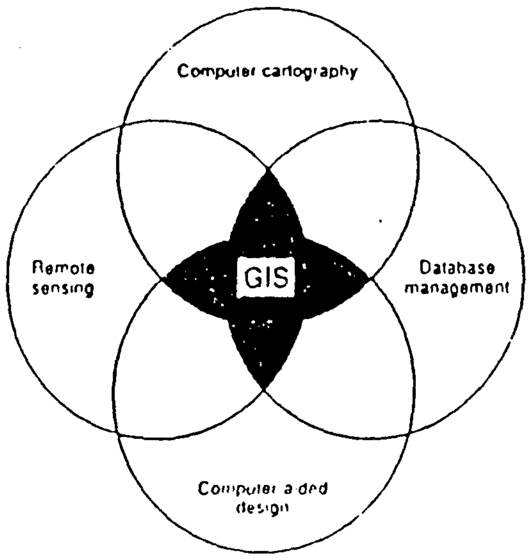


Fig. 2.12 Relationship between GIS and other information systems.

2.9.2 COMPUTER CARTOGRAPHY

Computer cartography systems focus on data retrieval, classification and automatic symbolization. They emphasize display rather than retrieval and analysis. Computer cartography systems utilize simple data structures which lack information on topology. They can be linked to a database management system but only simple retrieval operations are normally undertaken. Computer cartography systems usually have many facilities for designing maps and producing high quality outputs in vector format.

2.9.3 DATABASE MANAGEMENT SYSTEMS (DBMS)

They are well developed software systems optimised for storing and retrieving non-graphic attribute data. They have limited graphical retrieval and display capabilities. DBMS are designed for the short-term retrieval and update of relatively small quantities of data and lack anything other than simple analytical functions. They have very limited capabilities for implementing spatial analytical operations.

2.9.4 REMOTE SENSING SYSTEMS

They are designed to collect, store, manipulate and display raster data typically derived from scanners mounted on aircraft or satellite platforms, although they can usually handle any data in raster format. Most remote sensing systems have limited capabilities for handling vectors and, therefore, are unsuitable for operation by network analysis and producing high quality plots from coordinate geometry which are best carried out using data in vector format. They usually have limited capabilities for handling attribute data and only poor links to DBMS. Though they have some sophisticated facilities for enhancing and classifying data.

2.10 Advantages Of GIS Over Other Systems

All these above systems have few features in common with GIS. Geographical information system, however, have a number of other features not available in other systems. GIS have overcome the functionality problems or limitations faced by different systems separately. GIS has the capability of data input and encoding, data manipulation, data retrieval, data analysis, data modelling, data display and database management. They are explained in detail under heading function of GIS.

2.11 Functions Of GIS

Various capabilities of GIS functioning in brief are explained below as:

A. DATA INPUT AND ENCODING

(i) Data capture, e.g. digitizing and integration of data.

(ii) Data validation and editing,e.g. checking and correction.

(iii) Data structuring and storage, e.g. construction of different kinds of surfaces and data coding.

B. DATA MANIPULATION

(i) Structure conversion, e.g. conversion from vector to raster and vice-versa (Fig. 2.13).

(ii) Geometric conversion, e.g. map registration, scale changes, various transformations, map projection change, etc. Some fundamental geometric manipulations of GIS database files (Dangermond, 1983) are shown in Fig. 2.14.

(iii) Generalisation and classification, e.g. reclassifying data, aggregating or disaggregating data.

(iv) Integration, e.g. combining layers of different surfaces.

(v) Enhancement, e.g. image edge enhancement.

(vi) Abstraction, e.g. calculations of area centroids and thiessen polygons.

C. DATA RETRIEVAL

(i) Selective retrieval of information based on user defined themes or criteria, including 'browse' facilities.

D. DATA ANALYSIS

(i) Spatial analysis, e.g. route allocation, slope and aspect.

(ii) Statistical analysis, e.g. histograms, frequency analysis, measures of dispersion, etc.

(iii) Measurement, e.g. line length, area and volume calculations, distance and direction, etc.

E. DATA MODELLING

(i) User defined views.

(ii) Logical and arithmatic model.

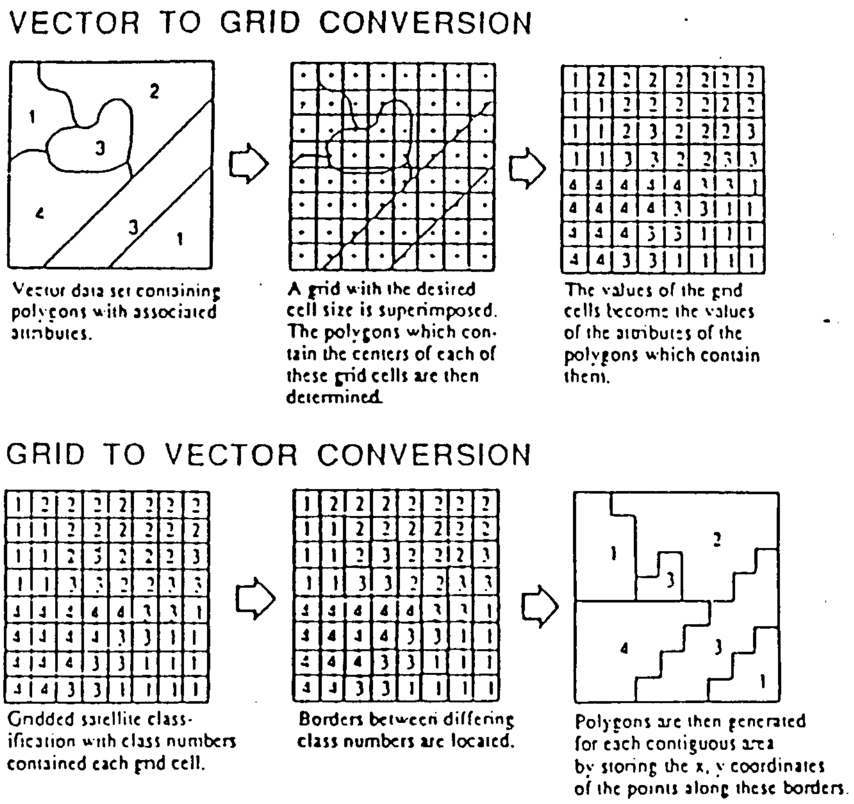


Fig. 2.13 Summary of a Vector to Raster - Raster to Vector conversion (from Robinson Barker, 1988).

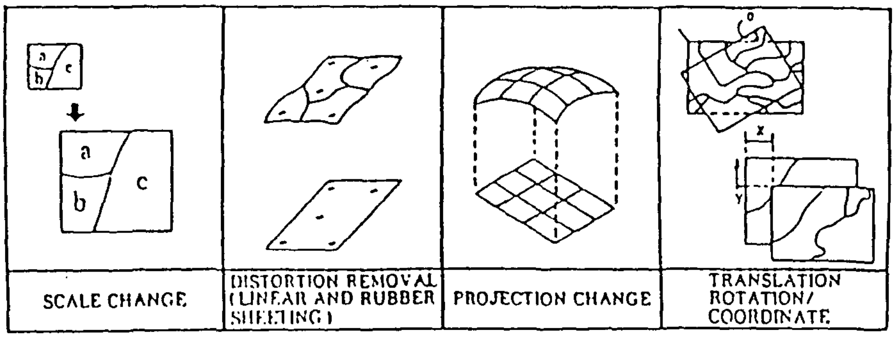


Fig. 2.14 Some fundamental geometric manipulations of GIS database files (after Dangermond, 1983).

(iii) Decision formula and tables.

(iv) Flow models.

(v) Network models.

(vi) 3-D models.

(vii) Allocation/siting models.

F. DATA DISPLAY

(i) Graphical display, e.g. maps, graphs.

(ii) Textural display, e.g. report writing, production of tables.

G. DATABASE MANAGEMENT

(i) Support and monitoring of multi-user access to the database.

(ii) Coping with system failures.

(iii) Communication linkages with other systems.

(iv) Updating of databases.

(v) Organization of the database for efficient storage and retrieval.

(vi) Maintenance of database for efficient storage and retrieval.

(vii) Providing a 'data-independent' view of the database.

2.12 GIS Applications

Geographical information system can be applied to many types of problem. Rhind (1990) has given a general classification of the types of general questions which GIS are frequently used to investigate (Table 2.4). The location question involves querying

Table 2.4 Basic questions that can be investigated using GIS (after Rhind,1990).

1.	Location	What is at..........?
2.	Condition	Where is it..........?
3.	Trend	What has changed.....?
4.	Routing	Which is the best way?
5.	Pattern	What is the pattern ?
6.	Modelling	What if..............?

a database to determine the types of features which occur at a given place. The condition question is really the converse, since it involves finding the location of sites which have certain characteristics. The other questions (Table 2.4) are more complex and involve some type of spatial analysis. Pattern question allows environmental and social scientists and planners to describe and compare the distribution of phenomenon and to understand the processes which account for their distribution. Modelling allows different models to be evaluated.

In general, GIS applications are made use of in map generation, representation of the layers captured by remote sensing or map digitising (Fig. 2.15), database management and spatial analysis, etc. Dangermond (1983) showed some grid based analytical techniques used in GIS (Fig. 2.16). Its applications are widely used in the fields of agriculture, botany, computing, economics, mathematics, photogrammetry, remote sensing, zoology, geography, etc. It's applications are used to support description, analysis, understanding, planning and realization of change in the world.

2.13 GIS In Fishery Investigations

Very little efforts have been made to make use of GIS techniques in fishery investigations. Investigations for fishery resource potential requires a vast amount of data on fish catches, meterological data, waves, currents, tides, sea surface temperature, planktons, upwelling zones, etc., and all these need

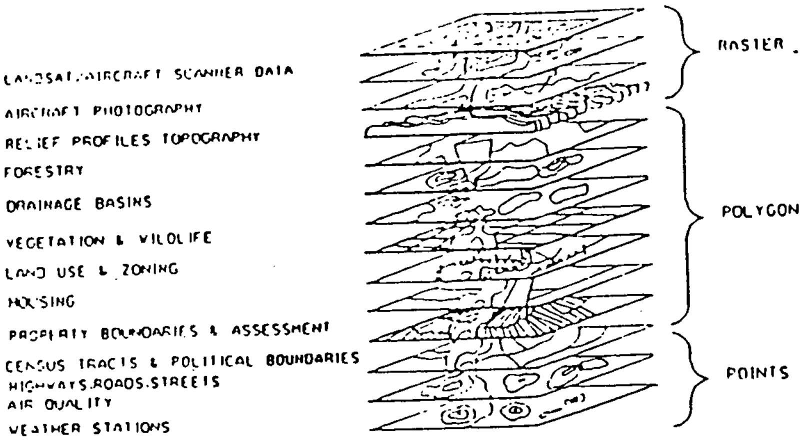


Fig. 2.15 Representation of the layers captured by RS or Map digitising (from Goodenough, 1988).

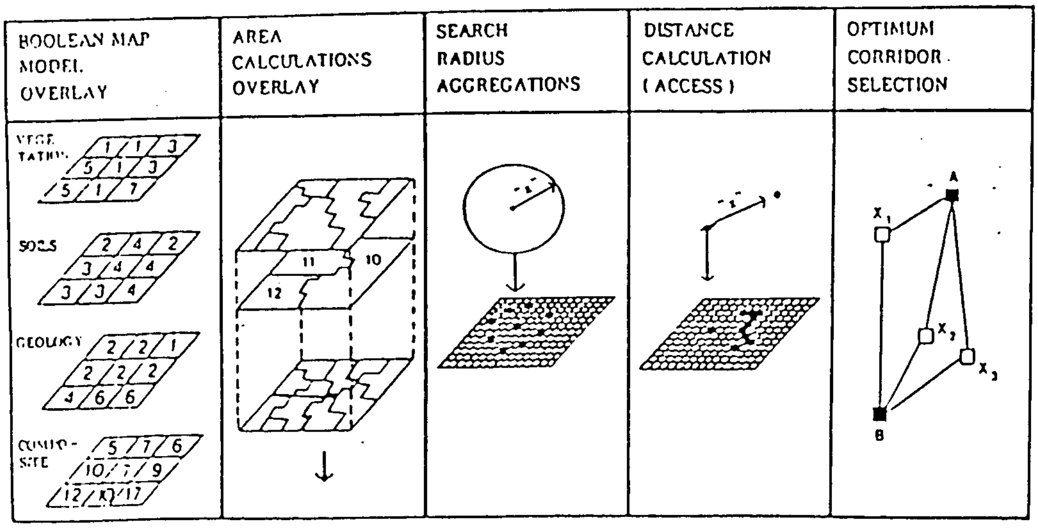


Fig. 2.16 Some grid-based analytical techniques (after Dangermond, 1983) used in GIS.

to be updated on a regular basis. GIS and Remote Sensing techniques can be of great help, in first of all providing information on few physical, chemical and biological parameters of oceans and secondly updating and analysing these data for a fast and accurate assessment of fisheries in the region. Capabilities of GIS and remote sensing techniques are immense and should be utilised for fishery investigations.

Synoptic viewing, repetitive coverage, capture, storage, analysis and retrieval are the various important tasks needed for fishery investigations, which are easily possible through GIS and remote sensing techniques. Though ground-truth or sea-truth is an important and un-avoidable step to be taken for validation or comparison of remote sensing data with field investigations. Ma Ai Nai (1993) of China has attempted a few remote sensing information models for marine fishery investigations. Recently, Khalid and Sudarshana (1994) attempted some analysis of shark fish resource across frontal boundaries in north-west Bay of Bengal using GIS techniques.

The present work utilises the potential of various image processing and GIS softwares like BILKO, IDRISI, PIZZAZ, SURFER, etc. for analysis of fishery data collected from the sea and for analysing and averaging the seasonal satellite remote sensing data for the study area.

CHAPTER THREE

MATERIALS AND METHODS

3.0 DESCRIPTION OF STUDY AREA

3.1 Introduction

India has a long coastline spanning over 7500 kilometers (Gopalakrishnan *et al.* 1991) and a continental shelf area of 0.5 million square kilometers with resource potential of 3.9 million tons (Indian Fisheries Statistics at a Glance, Government of India, 1992). India has high potential for marine fisheries development due to its geographic position in the central part of the Indian ocean. The continental shelf is generally broad along the west coast with the width ranging from 50 to 340km. The continental shelf along the east coast is relatively narrow and its width varies from 80-180km. The average width along the east and west coasts may be placed at about 40 and 75 kilometers, respectively (National Natural Resources Management System, App. Note. OC. 2, 1992). The extent of the area in the continental shelf and slope along the Indian Exclusive Economic Zone (EEZ) constitutes nearly 449.5 thousand square km (Sudarshan *et al.*, 1990). Exclusive economic zone is the area in which a country has full jurisdiction where marine resources can be exploited. It extends up to 200 nautical miles (1Nm = 1.852km) from the coast towards the sea. Indian EEZ covers an area of about 2.02 M square km, out of which EEZ off West coast alone comprises 42.6% and off East coast covers 27.8% area.

3.2 North-West Bay Of Bengal: The Study Area

North-west Bay of Bengal was selected as the study area. It lies between 18°-21° N and 84°-89° E (Fig. 3.1) in north-east coast of India. This area covers political area of Orissa, West Bengal and some portion of Andhra. These states are among the main maritime states of India which have registered relatively high level of growth rate in marine fish production during the VIth and VIIth plans.

The area selected for the study covers approximately 11% of the total Indian coastline (John and Sudarshan, 1990). It has a coastline covering a part of 974km of Andhra coast, 476km of Orissa coast and 158km of West Bengal coast. Columnar productivity of north-west Bay of Bengal is around 30% higher than the Arabian sea (Sudarshan, 1991). It explains that Bay of Bengal is one of the richest potential fishing zones along the Indian coast in terms of both quantity and quality.

Coastline along the study area is traversed by the presence of a number of creeks, estuaries, lagoons, bays and lakes, culminating into north-west portion of Bay of Bengal.

3.2.1 ORISSA COAST

It constitutes 6.3% of the total coastline of India, continental shelf area upto 200m depth is about 24000 square km. In southern part of the coast, the shelf is narrow whereas coast off north Orissa is characterised by several estuarine systems

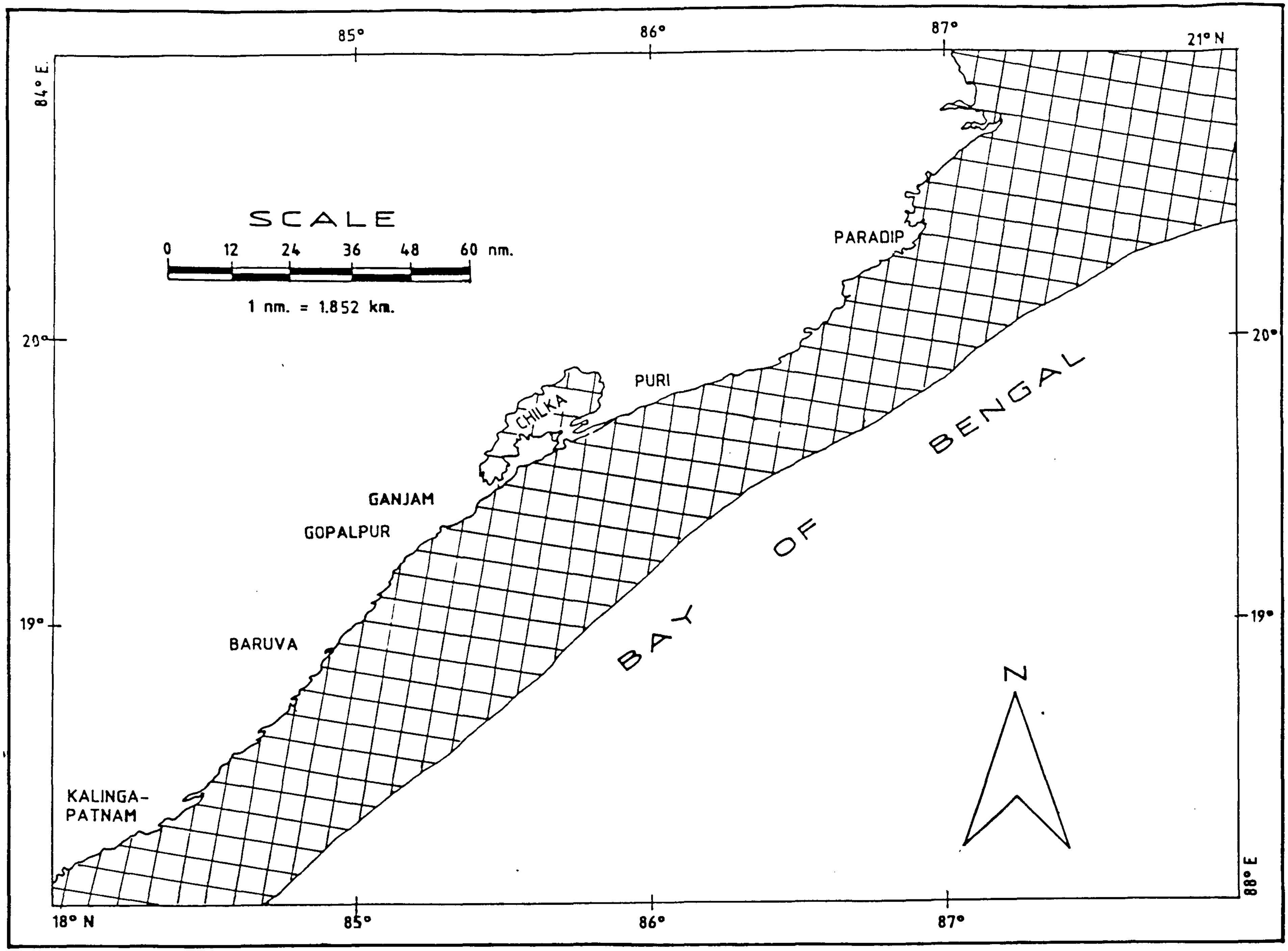


FIG. 3.1 MAP OF STUDY AREA

and an extended continental shelf. Important major rivers flowing into the Bay of Bengal in this part of coast are the Mahanadi, Devi, Brahmani and Dhamra. Chilka lake (area 1035 square km), the longest lagoon in the country is situated in the southern part of Orissa. Continental slope along the coast in 200-300m depth range has an area of about 1220 square km (John and Sudarshan, 1990).

There are about 236 marine fishing villages in Orissa. Fishermen households are over 20,000 and fishermen population is about 1,26,000. Fishermen engaged in actual fishing are about 30,700 (FSI Bull.19, 1990). The number of crafts and gears being operated from the state is given in Table 3.1. The mechanised boats operating in Orissa coast are 871 of which about 60% are trawlers and rest are gill netters.

Annual fish production and details of growth rate in Orissa are given in Table 3.2. Orissa contributes about 2.95% of the marine fish production in the country. The trend in marine fish landings during the 1980s indicates an impressive annual growth rate of 7.5% against the national average of 2.5%. The rate of fish production per unit area of the continental shelf is about 2.4 tons per square km, which is almost half of the all India average. Table 3.3 indicates the composition of catch along Orissa coast. It was seen that sciaenids form the major component (19.1%) of the catch followed by catfish (11.5%), pomfret (10.3%), elasmobranchs (6.2%) and hilsa (5.2%). Penaeid prawns

Table 3.1 Fishing craft and gears in Orissa and W.Bengal

Particulars	Orissa	West Bengal
Fishing craft		
Mechanised boats	871	1582
Motorised traditional craft	178	240
Non-motorised traditional craft	13520	4121
Total	14569	5943
Fishing gear		
Gill nets	21909	2467
Boat seines	3354	-
Fixed bag nets	2520	6200
Hook and lines	3267	869
Shore seines	1851	436
Trawl nets	1724	-
Others	1873	2839
Total	36498	12811

Source : Orissa - State Govt. (1988)

W.Bengal - Fishing craft : State Govt. (1985-86)
Fishing gear : CMFRI (1980)

Table 3.2 Marine fish production ('000 tonnes) and annual growth rate (%) in Orissa and W.Bengal, compared to all India figures

Year	Orissa		West Bengal		All India	
	Fish production	Growth rate	Fish production	Growth rate	Fish production	Growth rate
1979	32.0		60.0		1492.0	
1980	38.7	(+) 20.9	65.0	(+) 8.3	1554.7	(+) 4.2
1981	43.9	(+) 13.4	28.0	(-) 56.9	1444.8	(-) 7.1
1982	41.4	(-) 5.7	31.0	(+) 10.7	1427.5	(-) 1.2
1983	47.1	(+) 13.8	39.0	(+) 25.8	1519.3	(+) 6.4
1984	47.0	(-) 0.2	29.0	(-) 25.6	1779.4	(+) 17.1
1985	52.4	(+) 11.5	34.6	(+) 19.3	1734.2	(-) 2.5
1986	56.5	(+) 7.8	50.5	(+) 46.0	1716.9	(-) 1.0
1987-88	57.0	(+) 0.9	61.8	(+) 22.4	1658.1	(-) 3.4
1988-89	60.0	(+) 5.3	62.4	(+) 1.0	1817.4	(+) 9.6
Average		(+) 7.5		(+) 5.7		(+) 2.5

Table 3.3 Percentage composition of marine fish landing in Orissa and W.Bengal

Species/group	Orissa*	West Bengal**
Sharks, skates & rays	6.2	2.5
Cat fish	11.5	15.4
Hilsa	5.2	6.4
Other clupeids	22.5	14.5
Bombay duck	0.6	8.1
Perches	1.9	0.2
Jew fish (Sciaenids)	19.1	5.2
Threadfin bream	1.1	-
Ribbon fish	2.3	5.4
Horse mackerel	0.5	-
Other carangids	1.5	0.7
Silver belly	1.8	0.2
Pomfret	10.3	14.6
Mackerel	2.1	0.1
Seer fish	4.1	2.8
Penaeid prawns	4.3	2.9
Non-penaeid prawns	0.2	12.5
Squid & cuttle fish	1.1	0.3
Other fishes	3.7	8.2

Computed from: * Scariah et al. (1987); ** Philipose et al. (1987)

formed 4.3% and non-penaeid prawns formed 0.2%. Demersal stocks account for about 59% of the total marine fish production in Orissa (Scariah *et al.*, 1987; Phillipose *et al.*, 1987).

3.2.2 WEST BENGAL COAST

West Bengal coast constitutes around 2.1% of the Indian coastline. The continental shelf area is characterised by vast deltas formed by the Hoogly river, Thakuran river and Malda river. It has a shelf area covering about 27,000 square km, out of which half of the area falls within 50m depth contour forming a vast stretch of shallow sandy and muddy area.

In West Bengal there are around 303 fishing villages situated in the maritime districts of Midnapore and 24 Parganas. About 14,200 households are engaged in fishing and allied activities. Out of the total fishermen population of about 85,000 active fishermen are nearly 19,800 (John and Sudarshan, 1990). Table 3.1 depicts the type and number of crafts and gears being operated from West Bengal.

In West Bengal, mechanised boats are 1582, mostly gill netters and carrier boats. The fishing gear units are about 12,800 of which fixed bag nets account for about 48% and gill nets 20%. The share of West Bengal in total marine fish production in the country is about 2.86%. Table 3.2 also describes the details of annual fish production and growth rate in West Bengal.

Major contributing fish species to the fishery in West Bengal are catfish (15.4%), pomfret (14.6%), non-penaeid prawns (12.5%), Bombay-duck (8.1%) and hilsa (6.4%) (Scariah *et al.*, 1987; Phillipose, 1987). Proportion of demersal and pelagic components is about 59% and 41%, respectively (John and Sudarshan, 1990).

3.2.3 ANDHRA COAST

Andhra Pradesh has a long coastline of 974km. The study area encompasses a small portion of this coastline. The coast is traversed by Godavari river bringing sediments, etc. in the Bay of Bengal. It also has a rich fishery resource in its coastal waters.

3.3 Data Base

The data for the present study was procured from various sources. Fishery data and other ecological data were collected from fishery survey sea cruises of Fishery Survey of India, Bombay. Bathymetric data, etc., were obtained from Naval Hydrographic Office charts procured from Naval Hydrographic Office, Dehradun, India. The satellite data was procured from National Remote Sensing Agency (Department of Space), Hyderabad, India. General components of the present database are shown in Fig. 3.2.

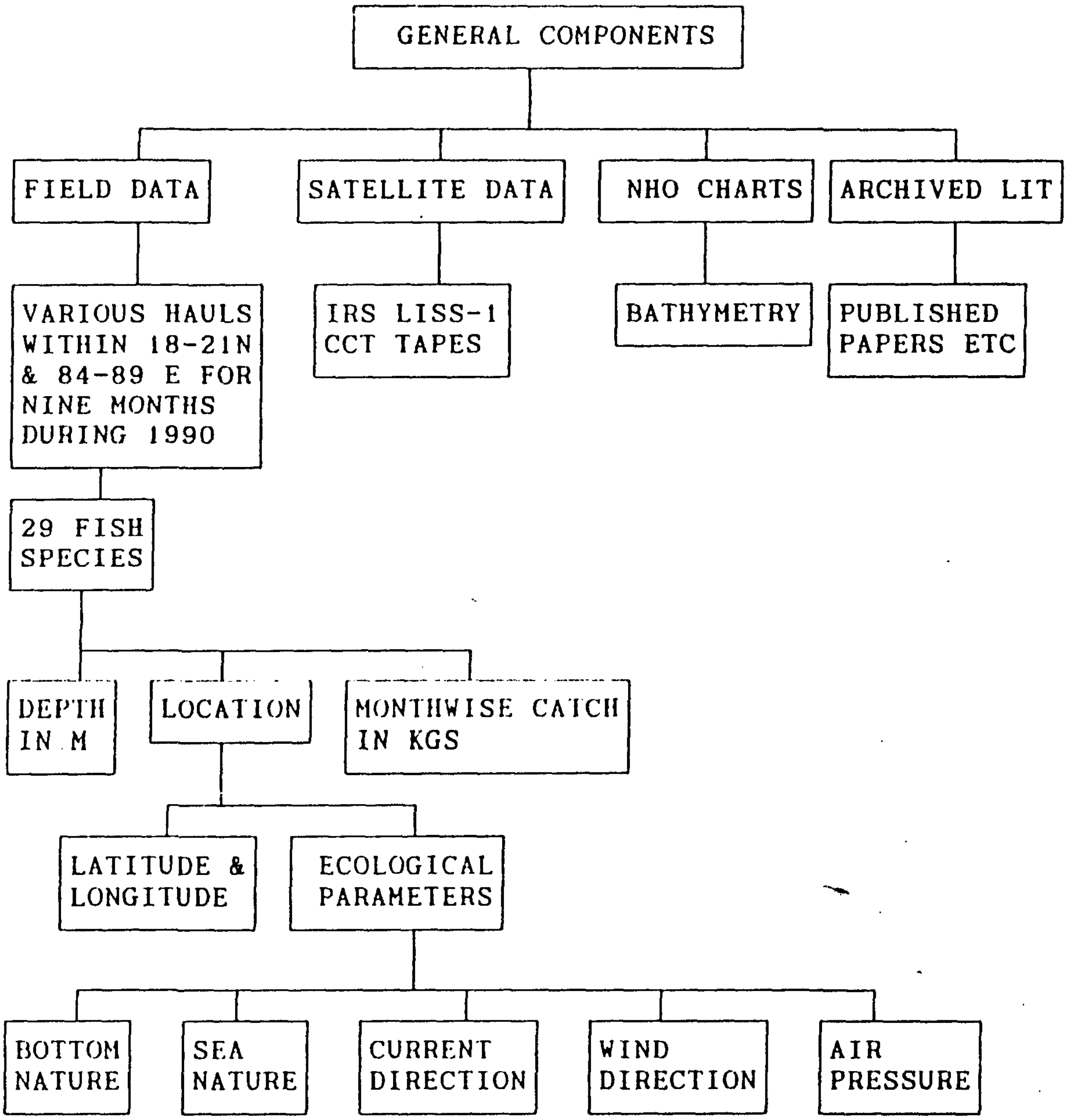


Fig. 3.2 Schematic sketch of general components of database used for the present study.

3.3.1 FISHERY SURVEY DATA

Fishery Survey of India is the nodal governmental agency to conduct fishery survey cruises in Indian ocean through its fleet of vessels. The general components of fishery survey data (Fig. 3.3) for the present study encompasses fish catch collected by cruises of vessel Matsya Shikari of Fishery Survey of India, Visakhapatnam. A total of nine months of data could be obtained for the year 1990. In the remaining three months i.e. January, September and October, the vessel was either idle or sailing in the area other than the study area. Therefore, the data for these months could not be obtained. The data, thus procured, was in respect of 9 months i.e February, March, April, May, June, July, August, November and December of the year 1990. Fishes were collected through a high opening 34m fish trawl with a codend mesh size of 80mm, at a trawling speed of 3.5 knots.

In trawl catches, a vast number of fish species were collected when the net was hauled out. The fish catch was released on vessel's deck and different species of fishes were separated and segregated in various trays for storage in fishhold having 100 ton capacity in the belly of vessel at -40° C temperature. The geographic location i.e the latitude and the longitude of each fish species caught was noted and the data of fish catch, so obtained, was entered in fish catch data sheets. The record of fishes were tabulated species-wise, haul-wise and weight-wise.

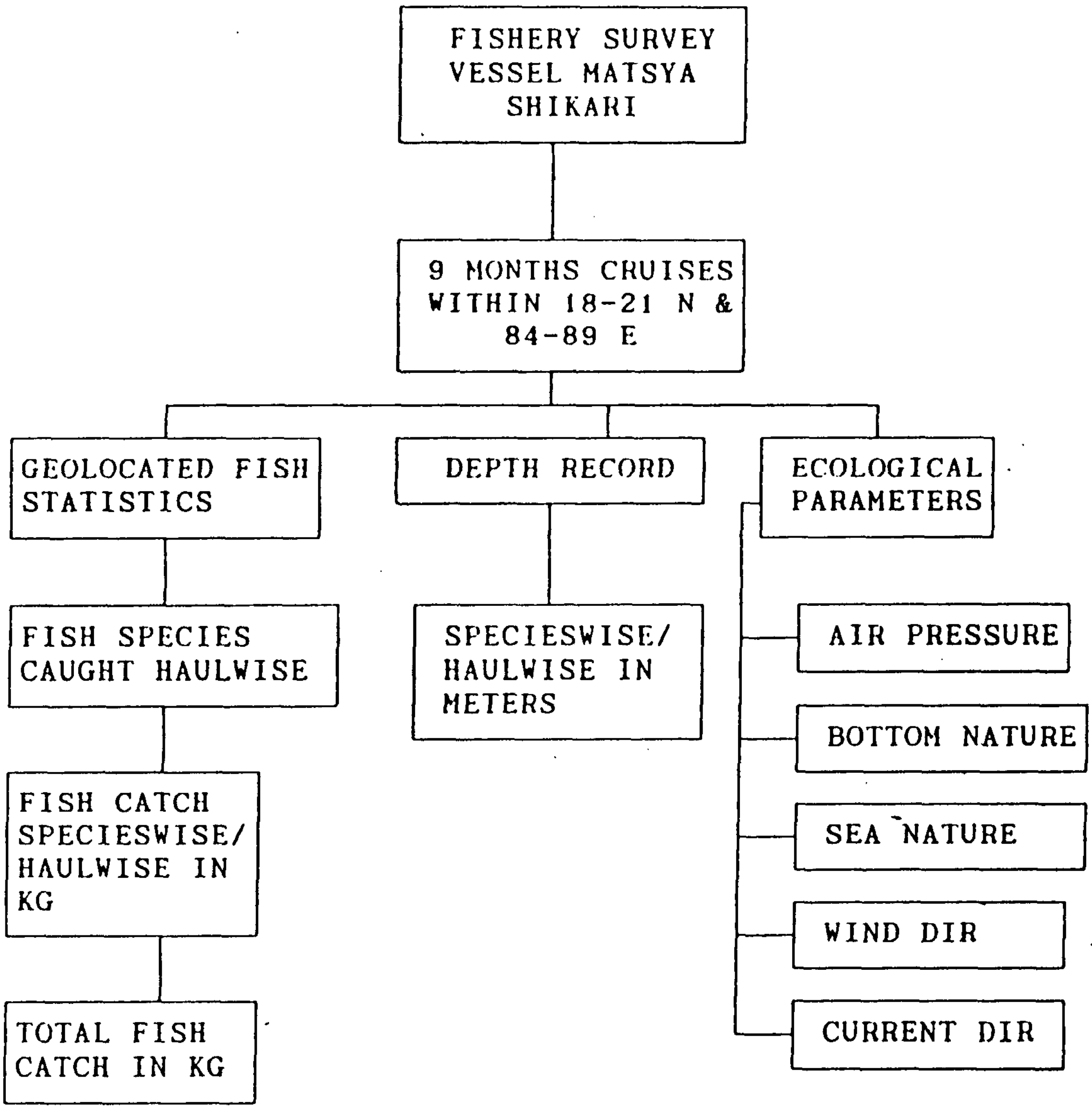


Fig. 3.3 Schematic sketch showing general components of fishery survey data.

Altogether, 41 species of fishes were collected as number of fish species varied from month to month. Sampling stations or number of hauls for each month varied from 26 to 48 (Table 3.4). This variation in sampling numbers was attributed to various factors like turbulence or roughness of sea, rainy season, depression in Bay of Bengal or sometimes due to mechanical problems of net drums, etc., mounted on ship, which are hydraulically operated which makes fishing operation difficult.

The vessel Matsya Shikari is fitted with various instruments and gadgets for aiding in navigational and fisheries net operationalisation, onboard facility of 'Satellite Navigator' which acts as global positioning system (GPS), and helps in fixing geographic location of each haul/sampling station. Satellite navigator is having a display monitor which shows in-situ latitude and longitude of the ship position with an accuracy of +10m. The Magnavox system (Sivadas, 1993) consists of a receiver in the ship to detect the presence of satellites and determine the latitude after undergoing complex calculations and giving corrections for azimuth, angle, speed of satellite, altitude, location, etc. The relative movements of satellites with respect to earth are made use of in the determination of the position of the ships in the sea.

Another important facility onboard ship for measuring depth (in meters) was 'ECOSOUNDER', an accoustic equipment (Sivadas, 1993) which transmits a sound beam vertically downwards

Table 3.4 Monthwise fish haul data.

MONTH	NO. OF HAULS
FEBRUARY	32
MARCH	48
APRIL	27
MAY	38
JUNE	31
JULY	45
AUGUST	26
NOVEMBER	46
DECEMBER	32
Total Hauls	325

travelling through the water column and returns back to the source of origin after striking the target (bottom of sea or any other obstacle) on the way. The recording unit remains enclosed in a glass case having a roll of paper moving continuously with a constant speed and the graph being marked by a marking pen. The depth is also continuously displayed in a digital monitor present along the graph. The accuracy of depth of the sampling stations is further verified from the Naval Hydrographic Office charts (NHO chart number 352, used for the present study) of upper east coast of India. The nature of the bottom of the sea for the sampling stations was obtained from hydrographic charts. The overall sea depth in the area of interest ranged between 50m to 200m. Actually, fish data during the cruises was collected on day to day/haulwise basis. For the present study, it was tabulated species-wise and month-wise as total catch in kilograms (Table 4.2).

3.3.2 ECOLOGICAL PARAMETERS

The geo-locations of the sampling stations help not only in determining the position of fish species, but also reveals other ecological parameters like depth, sea nature, bottom nature, current direction, wind direction, temperature, etc., which are simultaneously recorded at every sampling positions. The atmospheric pressure is recorded from barometer present onboard. Various ecological parameters as stated above were recorded at each sampling stations. These parameters were recorded through various onboard facilities like satellite navigator, echosounders, barometers and naval hydrographic charts of the region. The various ecological parameters were recorded in a coded language as per the coding given by Beaufort (Sverdrup *et al.*, 1942) classification.

3.3.2.1 Bottom Nature

The Sea bottom along the cruise track, during the sampling was found to be muddy and sandy-muddy within 18°-21° N and 84° -89° E. Bottom nature has been classified into different classes as per the characteristics of the sea bottom. Table 3.5 depicts classification of bottom nature in codes and its values between 0 to 6. The presence of various species of fishes in the demersal catches are also indicative of the bottom nature of the area indirectly. Echosounders also help in confirming the nature of sea bottom, as their markings on graph give information about even or uneven bottom nature.

3.3.2.2. Sea Nature

Fish catches were highly dependent on sea nature. Sea was usually calm throughout the year except in the monsoon months when it was usually rough. Sea nature was classified into four classes between 0 to 3 (Table 3.5), based on Beaufort classification. Sea nature has a decisive role in the presence of fish species and its catch. When sea was heavily rough, sampling was very tough or almost impossible, as highly unstable and turbulent movements of ship made net operation impossible.

Table 3.5 Ecological parameters with specific codes and its explanation as per Beufort (Sverdrup et al.,1942) classification.

CODE	PARAMETER SPECIFICATIONS			
	BOTTOM NATURE	SEA NATURE	CURRENT DIRECTION	WIND DIRECTION
0	Muddy	Rough	West	North
1	Sandy	Calm	South-West	South
2	Sand & Mud	Squally	North-West	West
3	Shingles	Choppy	East	East
4	Coral	_	South-East	North-West
5	Rocky	_	North-East	North-East
6	Shells	_	North	South-West
7	_	_	South	South-East

3.3.2.3 Wind Direction

Wind direction affects the movement of waves and currents and thus affecting the movements of fishes. Data on wind direction in north-west Bay of Bengal during the study period was recorded by the satellite navigator, and it was classified into eight classes between 0 to 7 (Table 3.5). During the study, wind direction showed a changing trend throughout the year in the study area.

3.3.2.4 Current Direction

Current direction is an important ecological parameter for fishery location and movement. Data on current direction in the study area during the study period was recorded by satellite navigator present onboard ship. Current direction was classified into 8 classes (Table 3.5) between 0 to 7. It was observed that the current direction showed a changing trend throughout the year during the study period.

3.3.2.5 Atmospheric Pressure

Atmospheric pressure at the sampling stations was directly recorded in mm of Hg (mercury) pressure from the barometer, an instrument present onboard the ship. Low atmospheric pressure was observed in Bay of Bengal whenever a depression was formed. It was observed that the atmospheric pressure fluctuated between range of 1000 to 1020mm of Hg during the year of study in the study area.

3.3.3 SATELLITE DATA

The data of IRS-1B LISS-1 i.e Indian Remote Sensing Satellite-1B, linear image self scanning sensor was used for the present study. The satellite data of IRS-1B were recorded in high density digital tapes (HDDTs) and were supplied in computer compatible tapes (CCTs) in all the four bands i.e blue, green, red and infrared. Three CCTs were procured from National Remote Sensing Agency (NRSA), Hyderabad, India, in spectral bands between 0.4 to 1.1mm wavelength representing the general time frame of field data obtenance. These geo-coded CCT data were supplied along with their negatives of the whole scene of the area covered in each tape. The CCTs were mounted on VAX-11/780 Computers present in Regional Remote Sensing Application Centre (RRSAC), Dehradun, India, for reading header information. Header of each CCT contained information about number of scan lines present, geographic location of the scene in terms of row and path number (which is in a way comparable to latitude and longitude of geographic maps), date and time of satellite pass when it was recorded.

The area of interest for study was selected from CCTs and transferred into floppies as geocoded subscene (512 X 512 pixel size) data for various analysis and transformation on PC-AT using a number of Image processing and Geographical Information System softwares. The satellite data used for the present study covered an area between 19°-21° N and 84°-89° E. The various specifications of CCTs used for the study are given in Table 3.6.

Table 3.6 Specifications of CCT's used for the study (IRS-1B, LISS-1 satellite data).

S.NO	CCT OF AREA	ROW NO.	PATH NO.	TIME OF DATA COLLECTION
1	CHILKA	54	20	3 Times each to generally represent the time of data collection from field experiment
2	PARADEEP	53	19	
3	KONARKA	54	19	

3.3.4 NAVAL HYDROGRAPHIC OFFICE DATA

Naval Hydrographic Office (NHO), Dehradun, is a pioneering governmental agency in India which publishes hydrographic charts as an aid to sailors. The present study obtained its database for bathymetry, bottom nature of sea, etc. for the sampling stations from NHO charts. The chart number 352 at 1:300,000 scale was used for the data extraction.

3.3.5 PUBLISHED LITERATURE DATA

An intense literature search was made for published data on various aspects of fisheries for north-west Bay of Bengal. It is referred in detail in Chapter 1 of this thesis. Various sources of data information were Fishery Survey of India bulletins, resource information series, fish catch data sheets, various abstracting International/National journals, reports, lecture notes, etc.

3.4 Graphic Transformation Of Fishery Data and Overlay

Spatio-temporal data from fishery cruises for nine months for an area between 18°-21° N and 84°-89° E in north-west Bay of Bengal were collected and were subjected to graphic transformation. The data collected was in random form depicting the quantity and type of fish species caught with their precise geographic location in latitudinal and longitudinal attributes.

Various steps involved in graphic transformation of data and overlay are as under:

3.4.1 DATA INTERPOLATION AND RASTERISATION

3.4.1.1 Data Input Format

The data obtained from the sea cruise from its fish catches was recorded in fish catch data sheets showing area of fish catch, quantity of fish catch species-wise, ecological and physical parameters like bottom nature, sea nature, wind direction, current direction, atmospheric pressure and depth where they were caught. To feed this data in computer for interpolation and rasterisation, an input format was designed to enable this field data for analysis and conversion. A data input format was designed in SURFER software.

3.4.1.2 Methodology

In the present study, methodology involved in the analysis of data was in two phases. In phase-I, the fishery data and ecological parameters were analysed and in phase-II, the satellite data was subjected to various transformations and analysis.

3.4.1.3 Phase-I

Spatio-temporal data from fishery survey cruises for nine months for an area between 18°-21° N and 84°-89° E in north-west Bay of Bengal were collected. Fig. 3.4 describes

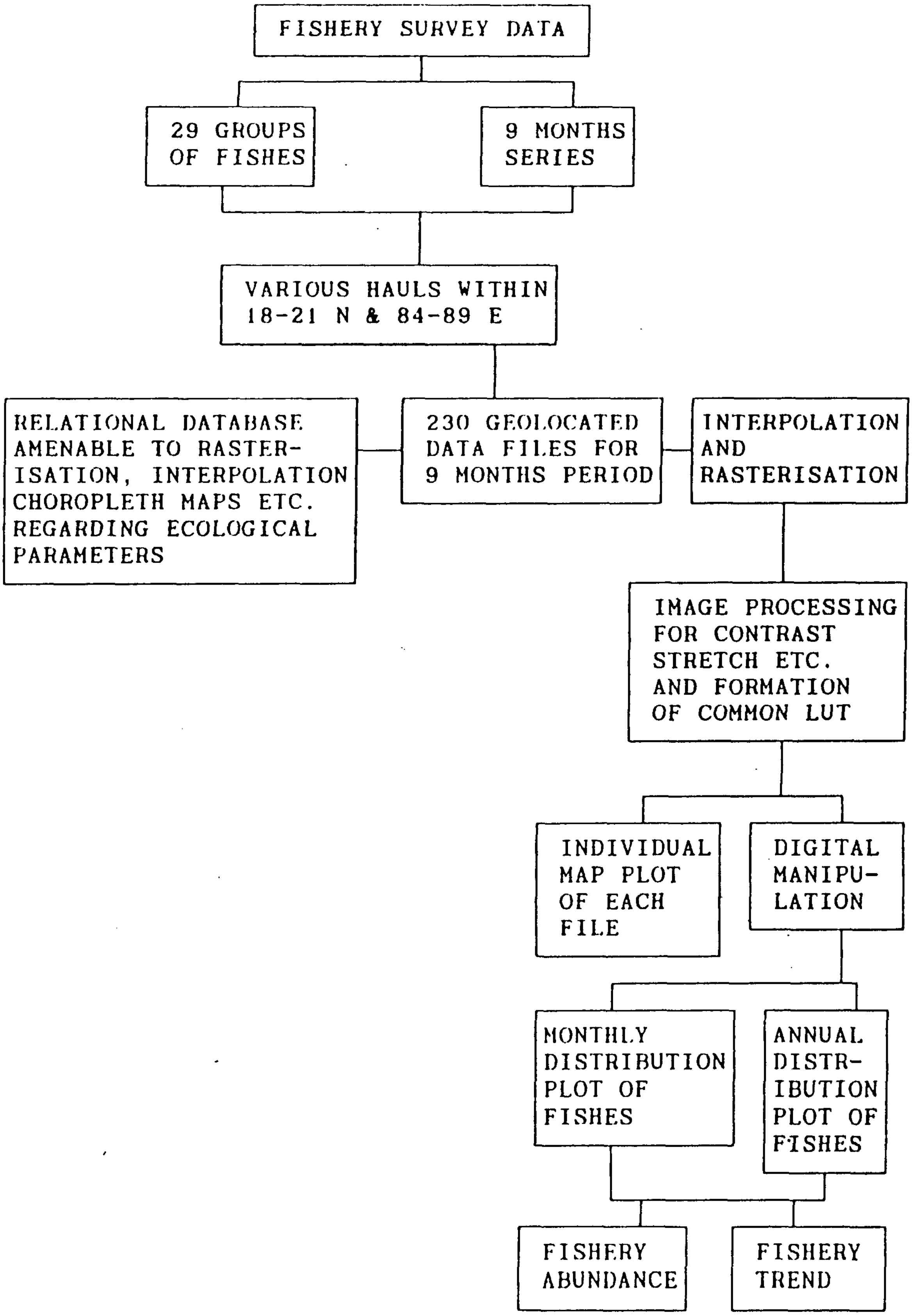


Fig. 3.4 Schematic sketch of methodology followed for fishery data analysis.

the various steps involved in the graphic transformation of the fishery data.

The data collected was in random form depicting the quantity and type of fish species caught with their precise geographic location in latitudinal and longitudinal attributes, but in irregularly distributed stations. Species-wise/location-wise and weight-wise data for 29 fish species for nine months period were selected. This data was tabulated as fish.dat files and was subjected to gridding for conversion to grid files through SURFER software by inverse distance gridding. This process helps in interpolation of the random data. The output of this step generated flat files in binary format. Then through the same software i.e. SURFER, images of different fish species were generated from grid files. Images thus generated were subjected to image processing for contrast stretch, etc., and a common Look Up Table (LUT) was prepared for the same. Then a grid was overlayed over the image through map option for geo-location of the availability of fish species. Then the fish species for every month were added and annual distribution plots for individual fish species were made. Header information was written for these image files for compatibility and printing through Pizzaz-plus and IDRISI software. The above mentioned steps were repeated simultaneously for ecological parameters like depth, gathered from the same sampling points for which fishery data was considered.

3.4.1.4 Phase-II

Satellite data of IRS-1B LISS-I (Plates 3.1-3.3) were procured from NRSA, Hyderabad, India for various transformations and studies through the following methodology (Fig. 3.5):

Geo-located data in four bands were procured for three seasons to generally represent the time of data collection from field experiments, covering the study area (19°-21° N and 85°-89° E). Each CCT gives an area of the study zone called as 'Scene' in remote sensing language. The satellite data in 18° and 84° E could not be used for studies as clouds mostly covered the study area in the sea. The CCT were then loaded on VAX- 11/780 computer of Regional Remote Sensing Service Centre (RRSSC), Dehradun, India, and area of interest (i.e. the study area) was extracted using VIPS-32 Software. From these scenes, the subscenes were created in 512x512 pixel size (512 being the scan lines and columns). Then false colour composite (FCC) were generated using 4,3,1 bands (4 being the infra-red band, 3 as red and 1 as blue). Photographs were taken for these FCC's. Then the whole scene was sampled into 5x5 sampled images for a synoptic view of the whole area and photographs were taken. Subscenes were changed to Dat.files through Kermit programme available in VIPS-32 software. Dat.files were transferred onto floppies for further analysis on PC-AT. On PC-AT, individual bands were extracted and composite image of 4,3,1 bands were formed for every subscene using IDRISI software.

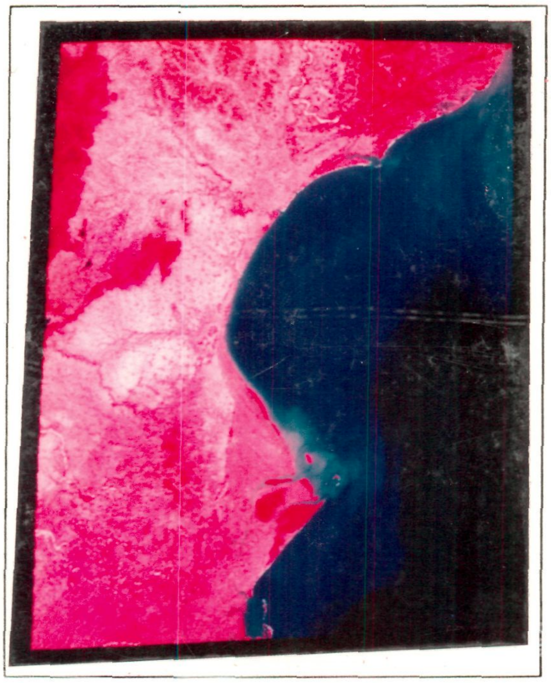


Plate 3.1 Sampled satellite image of a part of study area (Paradeep region)

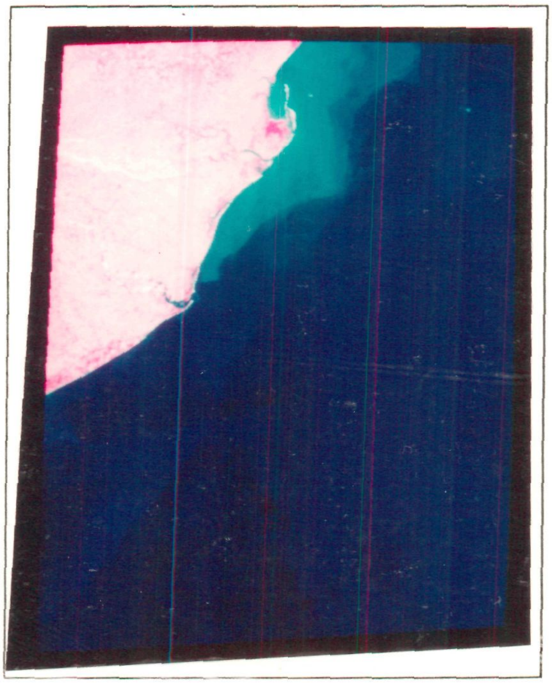


Plate 3.2 Sampled satellite image of a part of study area (Konark region)

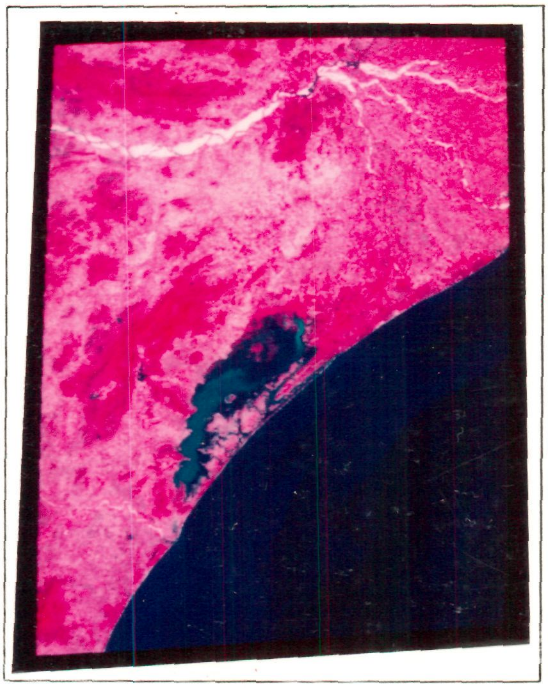


Plate 3.3 Sampled satellite image of a part of study area (Chilka region)

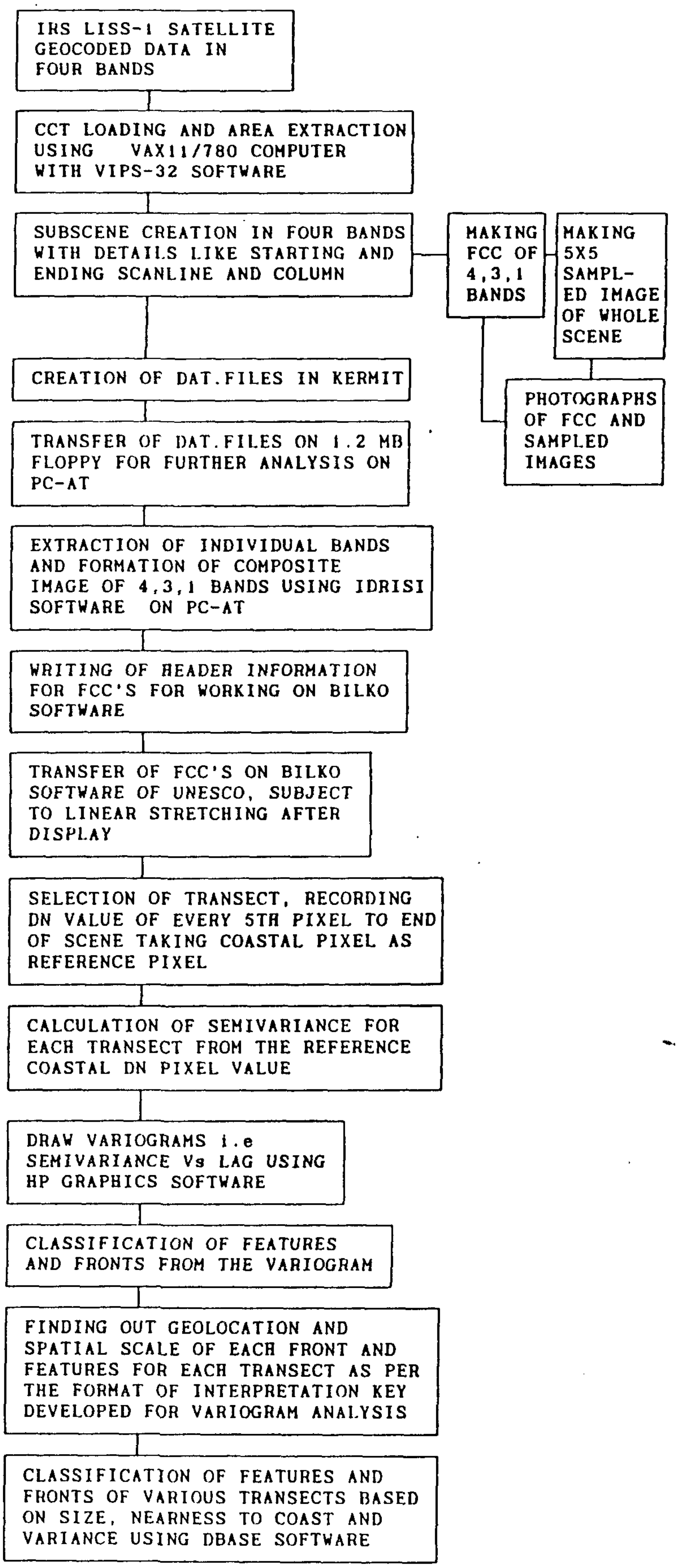


Fig.3.5 Schematic sketch of methodology followed for satellite data analysis.

Header information was written for FCC's generated from each scene for working on BILKO software of UNESCO. FCC's were transferred to BILKO software and were subjected to image processing like linear stretching, etc. Through cursor option, a transect was selected in the FCC image and Digital Number (DN) value was recorded for every fifth pixel from the coast to the sea till the end of the scene, taking coastal pixel as the reference and first pixel. The DN values were noted down in a format made specially for variogram analysis. Then Semi-variance was calculated for each DN value taking coastal pixel as the reference pixel. Latitude for each transect was calculated. Semi-variance Versus Lag (distance) graph or variograms (Fig. 6.2-6.41) were made in Harvard Presentation Graphics (HPG) software.

Classification of features and fronts from these variograms were done and tabulated in a variogram interpretation key format especially designed for variogram analysis. Geo-location of spatial scales for each front and feature of every transect was done. The data was fed to dbase software and classification of features and fronts of various transects based on size, nearness to coast, variance, etc., were done and database formed for coastal fishery resource interpretation.

CHAPTER FOUR

CHARACTERISTICS OF FISH DISTRIBUTION: SPATIO-TEMPORAL TREND

GENERAL INTRODUCTION

The study area has a rich fish resource with nearly forty-one species of fishes recorded during the nine months data collection. Fish resource data collected for nine months was thoroughly scanned fish-wise. Twenty-nine species of fishes were finally selected for comparison and studies with the satellite data obtained for the study region. The selected fishes are shown in Table 4.1, showing their occurrence in the number of months of the year. Out of forty one species of fishes recorded in the region, nearly twelve species of fishes were rejected for studies as most of these fishes were caught in insufficient quantity and also their occurrence was negligible during the year. Moreover, the area where these fishes were caught was also not falling in the area for which satellite data was available. The selected fish species were distributed as follows.

4.1 **Species distribution pattern**

Fishes selected for the study (Table 4.1) were found to be fairly distributed between 18°-21°N and 84°-88°30'E. Fishes were found fairly present almost all along the east coast. If we consider south to north direction of the coast, fishes were found to be present in ascending mode along the (south-north) coast. Species-wise, spatio-temporal distribution is explained as below:

Table 4.1 Selected fishes With their occurrence in months.

S.NO.	Fish name	Presence in number of months in a year	Average catch/month (in kg)
1	Sharks	8	21.8
2	Barracudas	8	108.7
3	Priacanthus	9	307.2
4	Psenus	7	300.4
5	Skates	5	56.7
6	Rays	7	69.6
7	Eels	5	3.3
8	Catfishes	9	1083.7
9	Ribbon fishes	7	109.0
10	Karkaras	8	173.0
11	Sea breams	5	6.0
12	Pomfrets	9	148.1
13	Dhoma	8	114.6
14	Lizard fishes	8	170.1
15	Nemipterids	9	892.0
16	Leognathids	6	560.0
17	Upenoids	9	637.4
18	Flatfishes	5	5.4
19	Prawns	5	3.2
20	Cuttle fishes	6	43.7
21	Clupeids	5	133.1
22	Carangids	9	232.1
23	Chorinemus	7	11.1
24	Mackerels	9	418.7
25	Decapterids	5	221.6
26	Seer fishes	9	59.8
27	Chirocentrus	6	8.8
28	Silver bellies	5	179.1
29	Squids	8	105.1

4.2 Spatio-temporal Distribution

Distribution and occurrence of selected fish species varies with space and time in its distribution. Table 4.2 shows month-wise and annual species-wise fish catch statistics. Following is the spatio-temporal distribution of twenty nine fish species (darker shade in each Fig. represents the quantity of fish distribution i.e. from light to dark in increasing order).

4.2.1 SHARKS

Sharks were caught in eight out of nine month catch. These were mainly found in areas between 18°-18°30'N and 84°-84°30'E; 19°30'N and 85°-85°30'E; 19°15'-19°45'N and 86°-86°30'E and 19°45'-20°45'N and 86°45'-87°45'E (Fig. 4.1 to 4.9) in their month-wise total annual distribution. The catch ranged from 0kg (as seen in August) to 63kg with an average of 21.8kg/month (Table 4.1). Sharks were caught in the depth range of 30 to 60 meters. They were not found in deeper water i.e. beyond 100 meters depth.

4.2.2 BARRACUDAS

Barracudas were recorded in eight out of nine month catches. These were mainly found in areas between 18°- 18°30'N and 84°-84°30'E; 19°-19°30'N and 84°45'-85°40'E'; 19°15'-19°45'N and 89°-86°30'E and 20°15'-20°40'N and 87°15' 87°40'E, as seen in their month-wise and total annual distribution (Fig. 4.10-4.18). The catch ranged from 0-557kg with an average of 108.7kg/month (Table 4.1). Barracudas were caught in the depth range of 40-70m.

Table 4.2 Monthly abundance of fish catch (in Kg) in the study area.

	MONTH								
FISH	FEB	MAR	APR	MAY	JUN	JUL	AUG	NOV	DEC
SHARK	15	5	14	15	38	63	0	57	25
BARRACUDA	0	133	07	128	22	52	7	557	73
PRIACANTHUS	90	132	01	657	444	696	3	709	33
PSENUS	25	1646	73	0	4	852	0	10	94
SKATE	120	0	138	232	0	0	0	17	04
RAY	0	40	47	235	18	165	0	45	77
EEL	0	0	0	2	5	11	6	0	6
CATFISH	2965	1549	1139	348	133	1257	142	1691	530
RIBBONFISH	300	0	46	44	83	46	443	0	19
KARKARA	156	54	160	170	141	40	161	130	545
SEABREAM	0	31	0	8	2	1	0	12	0
POMFRET	180	95	1	130	142	74	284	265	162
DHOMA	0	215	32	98	263	234	10	3	177
LIZARDFISH	0	104	240	544	127	265	15	200	36
NEMIPTERIDS	1090	240	39	945	1087	908	170	2949	600
LEOGNATHIDS	0	0	125	940	907	440	0	1759	869
UPENOIDS	115	350	994	826	529	362	113	755	1693
FLATFISH	0	4	29	0	9	2	0	0	5
PRAWN	0	0	5	0	9	4	7	4	0
CUTTLEFISH	0	111	77	0	4	84	0	70	48
CLUPEIDS	0	0	119	0	90	25	739	225	0
CARANX	397	251	214	246	31	195	73	406	276
CHORINEMUS	0	5	0	16	21	23	10	12	13
MACKEREL	315	235	45	315	11	1441	33	467	907
DECAPTERIDS	405	30	897	0	0	98	0	565	0
SEERFISH	2	1	3	42	44	73	42	147	185
CHIROCENTRUS	0	4	0	0	3	1	9	31	32
SILVERBELLY	140	120	0	180	6	0	1166	0	0
SQUID	130	40	146	350	0	58	124	64	34

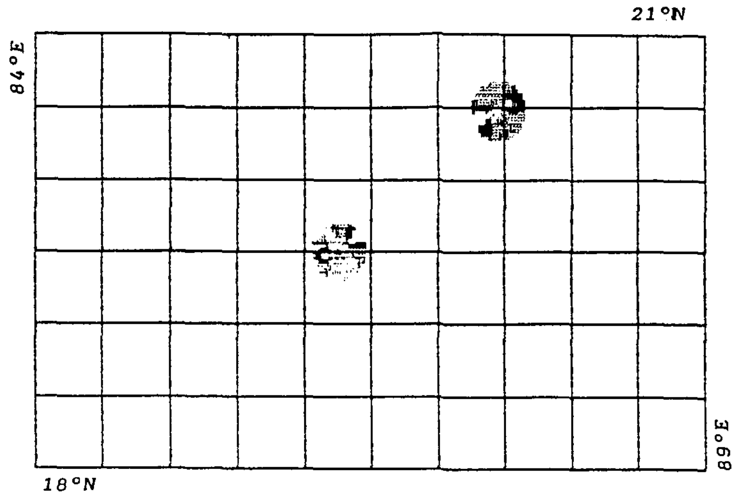


Fig. 4.1 Spatial distribution of Shark during February

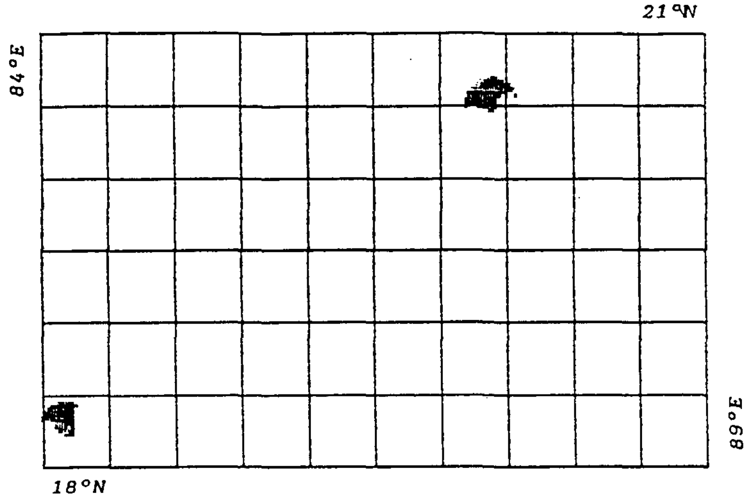


Fig. 4.2 Spatial distribution of Shark during March

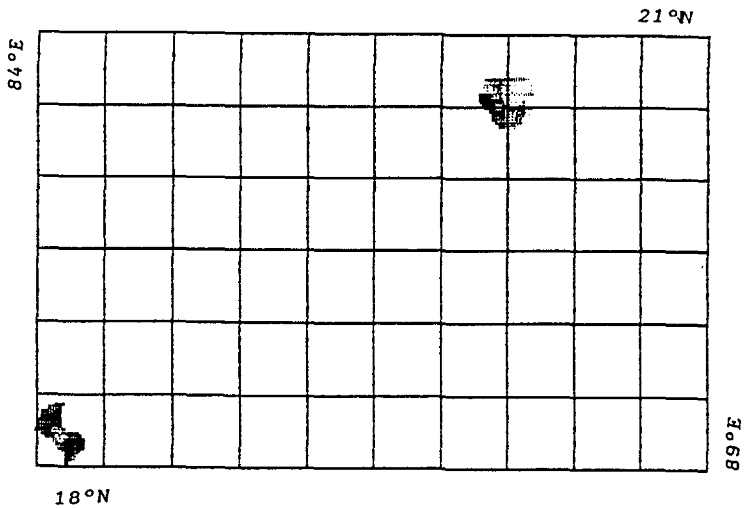


Fig. 4.3 Spatial distribution of Shark during April

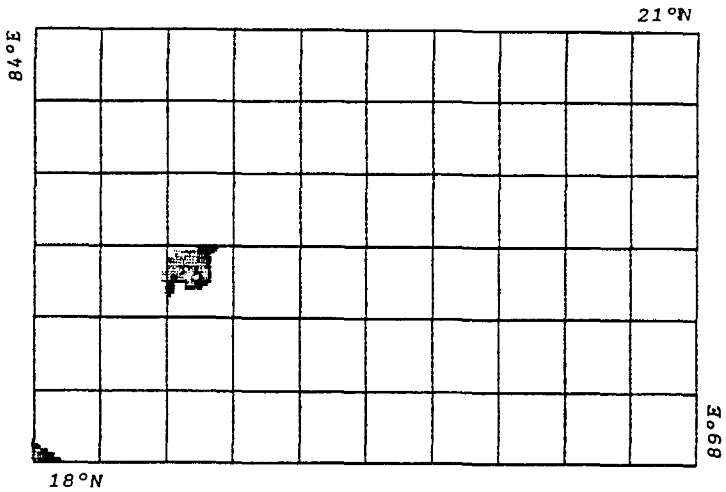


Fig. 4.4 Spatial distribution of Shark during May

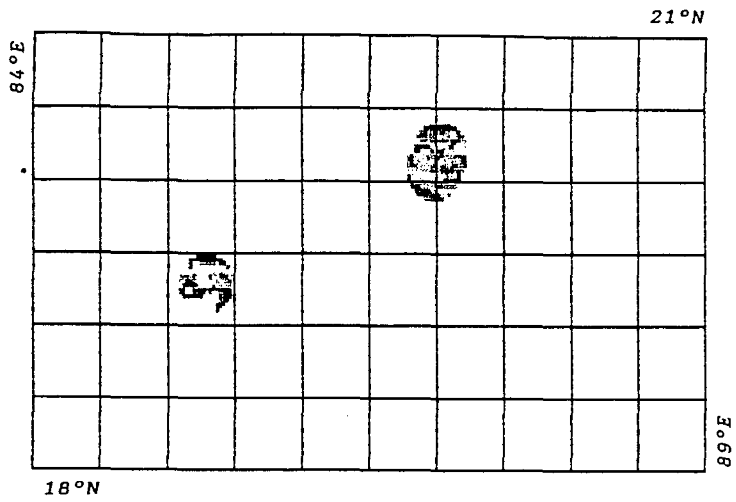


Fig. 4.5 Spatial distribution of Shark during June

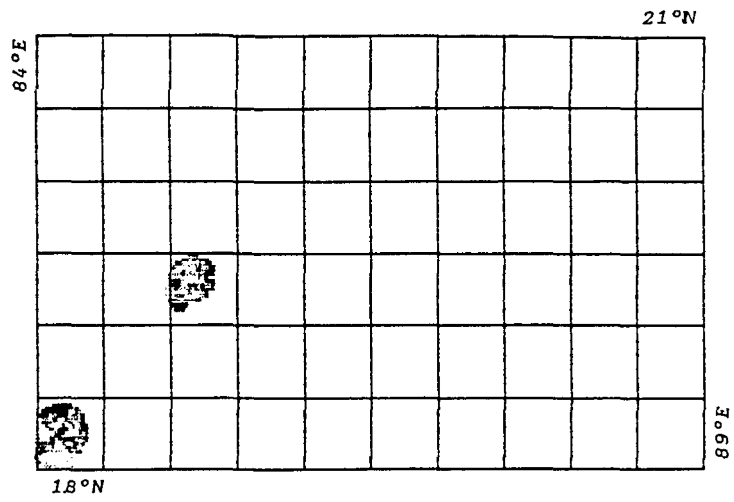


Fig. 4.6 Spatial distribution of Shark during July

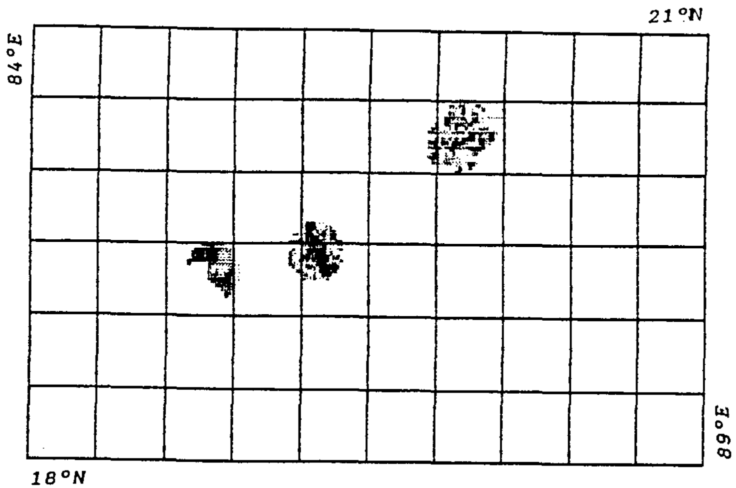


Fig. 4.7 Spatial distribution of Shark during November

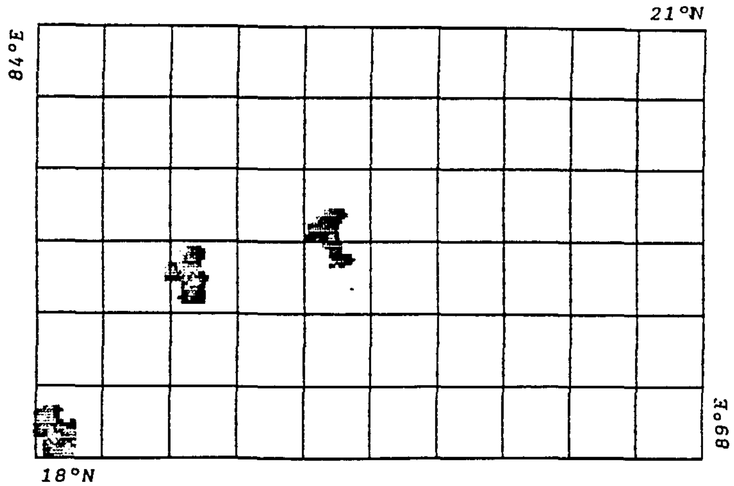


Fig. 4.8 Spatial distribution of Shark during December

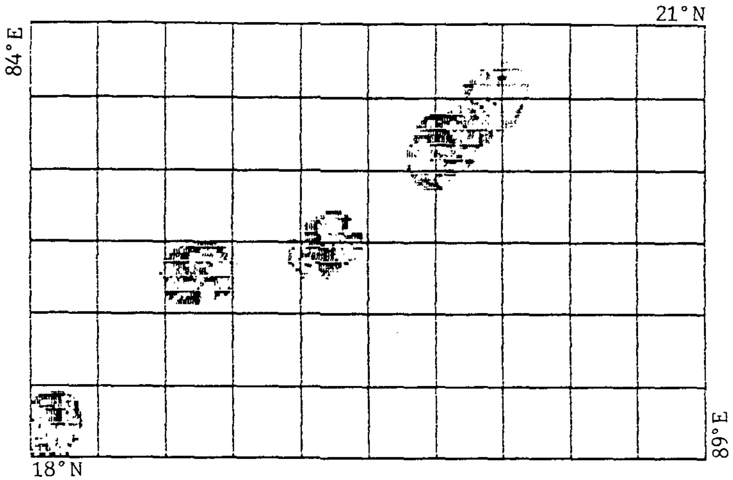


Fig. 4.9

TOTAL ANNUAL DISTRIBUTION OF SHARK IN NORTH WEST BAY OF BENGAL

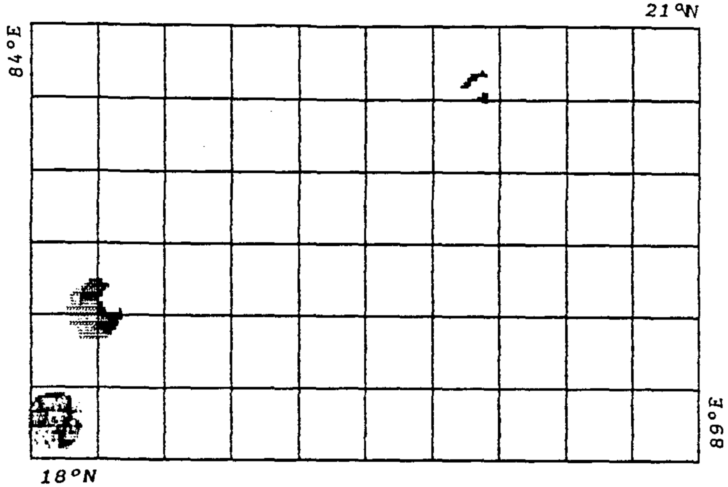


Fig. 4.10 Spatial distribution of Barracuda during March

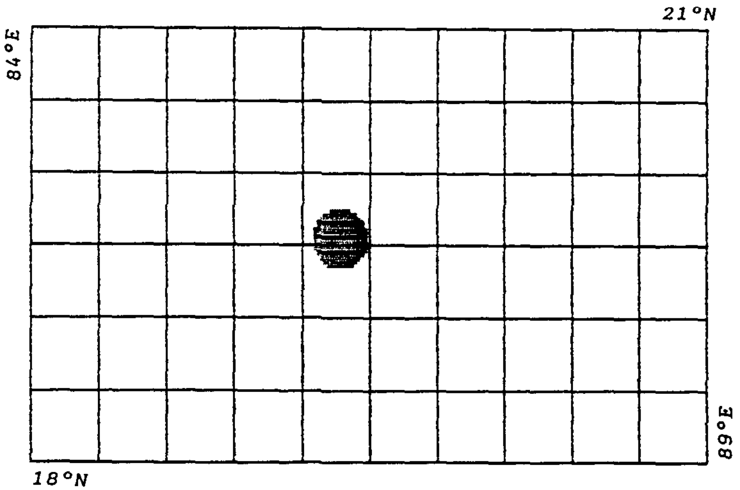


Fig. 4.11 Spatial distribution of Barracuda during April

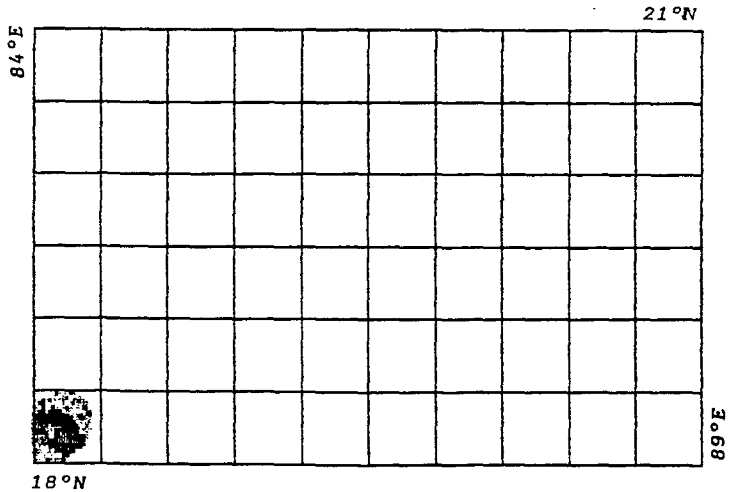


Fig. 4.12 Spatial distribution of Barracuda during May

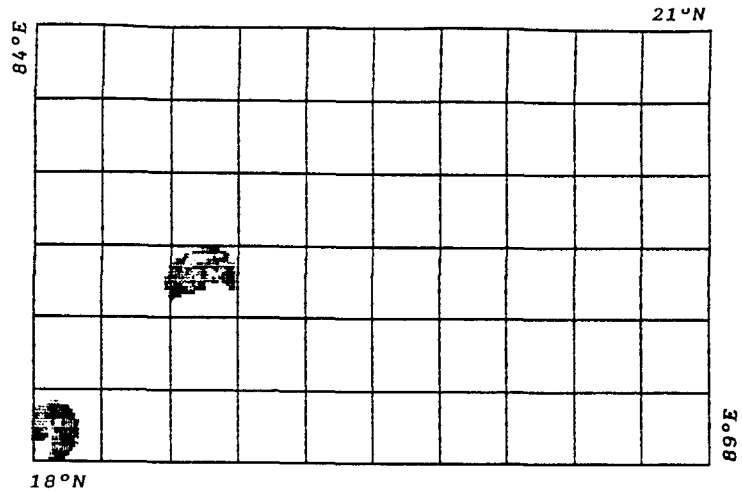


Fig. 4.13 Spatial distribution of Barracuda during June

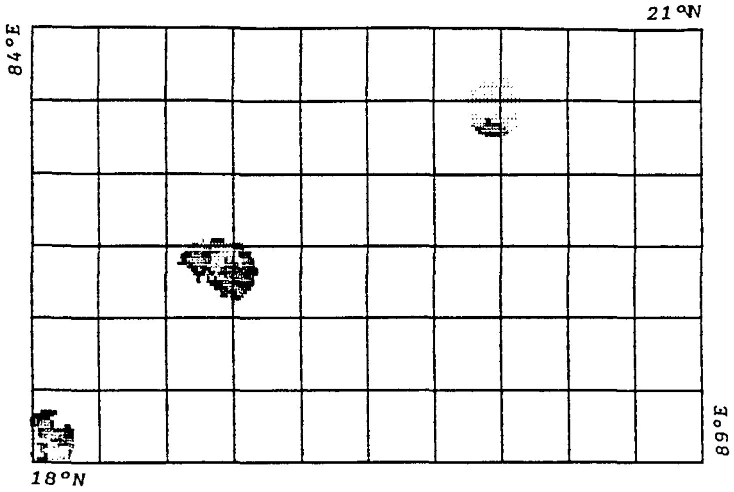


Fig. 4.14 Spatial distribution of Barracuda during July

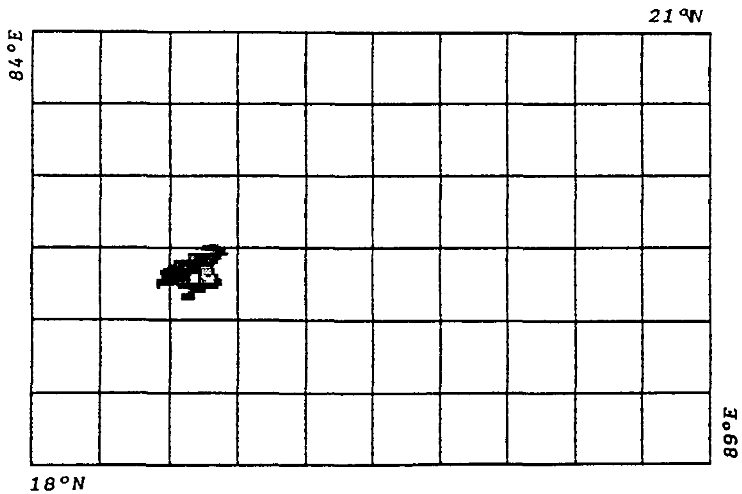


Fig. 4.15 Spatial distribution of Barracuda during August

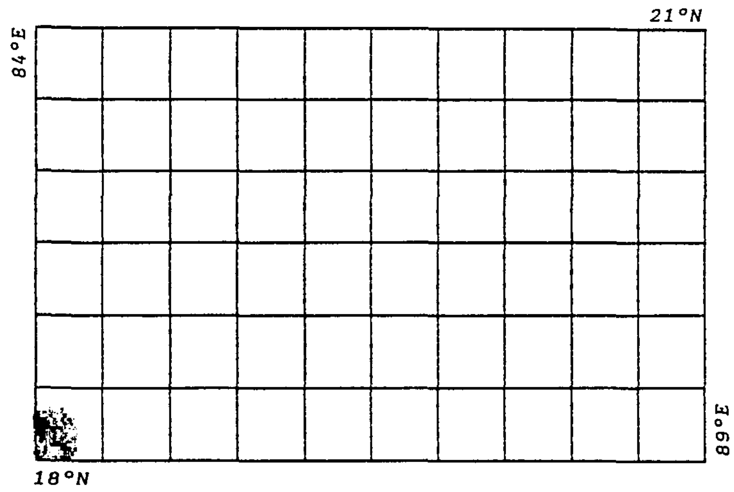


Fig. 4.16 Spatial distribution of Barracuda during November

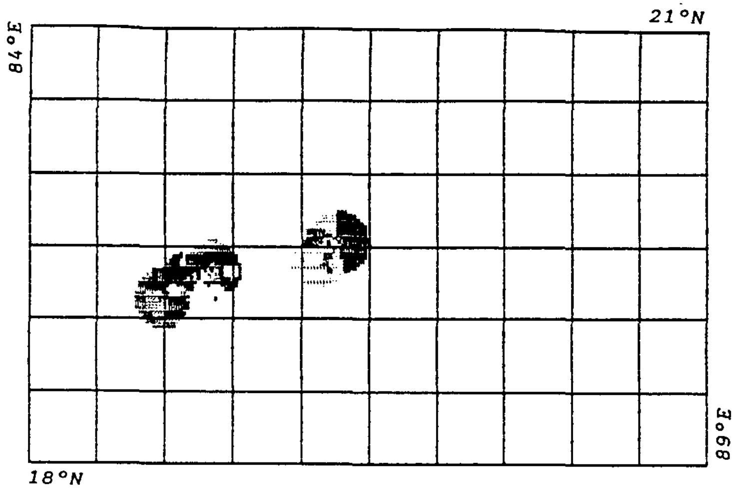


Fig. 4.17 Spatial distribution of Barracuda during December

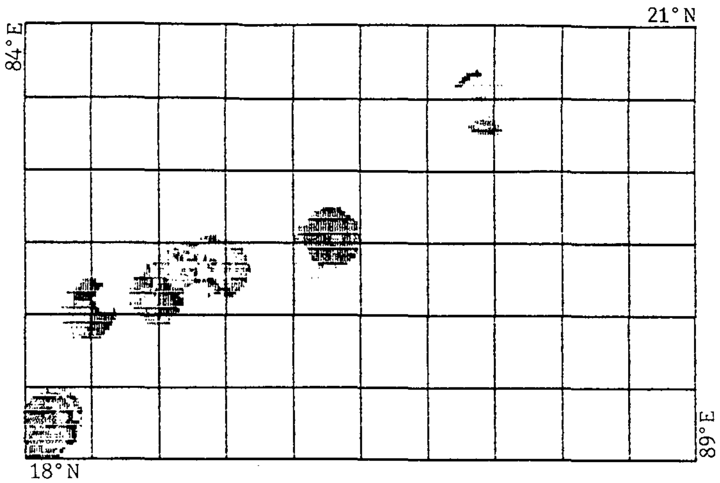


Fig. 4.18

TOTAL ANNUAL DISTRIBUTION OF BARRACUDA IN NORTH WEST BAY OF BENGAL

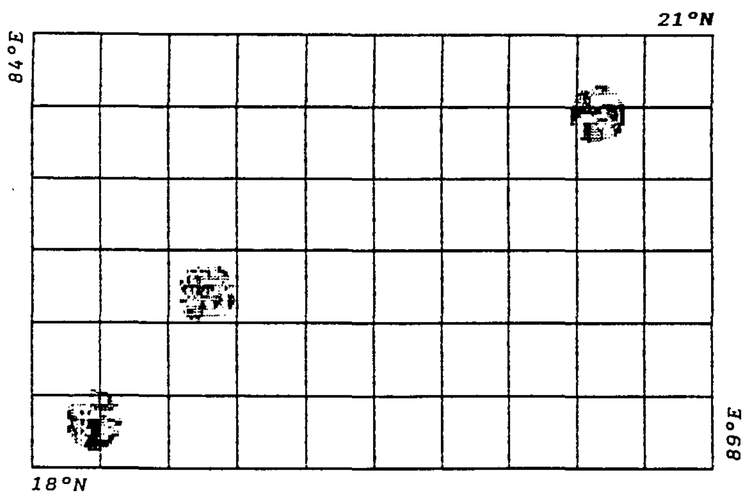


Fig. 4.19 Spatial distribution of Priacanthus during February

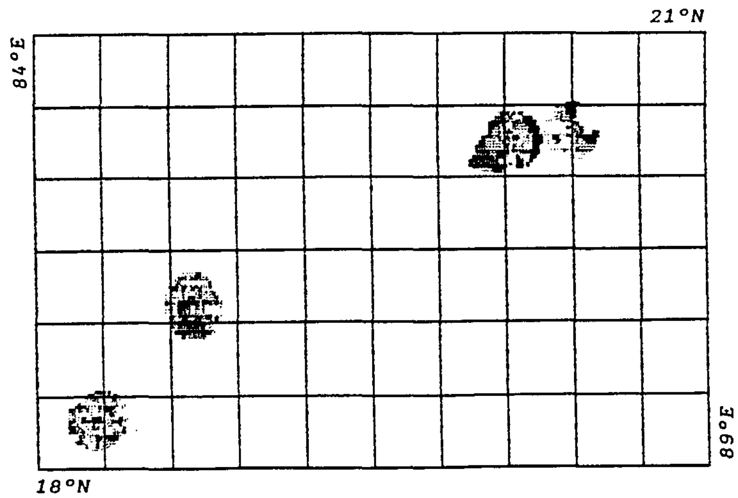


Fig. 4.20 Spatial distribution of Priacanthus during March

4.2.3 PRIACANTHUS

Priacanthus were caught in all the nine month catches. They were mainly found in areas between 18°10'-18°40'N and 84°15'-84°45'E; 18°20'-18° 45'N and 84°45'-85°25'E; 18°50'- 19°25'N and 85°-85°30'E; 20°-20°30'N and 87°15'-87°40'E and 20°10'-20°40'N and 87°45'-88°25'E (Fig. 4.19-4.28) in their month-wise and total annual distribution. The catch ranged from 1-709kg with an average catch of 307.2 kg/month (Table 4.1). Priacanthus were caught in deeper waters between 100-250m depth. They were never caught in shallower water.

4.2.4 PSENUS

Psenus were caught in seven out of nine month catches. They were mainly found in areas between 18°-18°25'N and 84°- 84°20'E; 19°-19°30'N and 84°50'-85°30'E; 19°50'-20°15'N and 86°20'-87°15'E and 20°15'-20°40'N and 87°50'-88°10'E (Fig. 4.29-4.35) in their month-wise total annual distribution. The catch ranged from 0-1646kg with an average catch of 300.4 kg/month (table 4.1). Psenus were caught in the depth range of 39-100 meters, but in one month (June) it was caught in a depth of 158 meters.

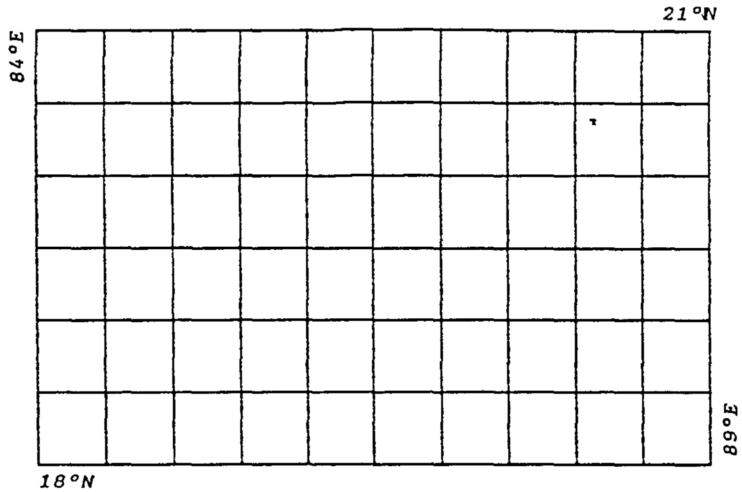


Fig. 4.21 Spatial distribution of Priacanthus during April

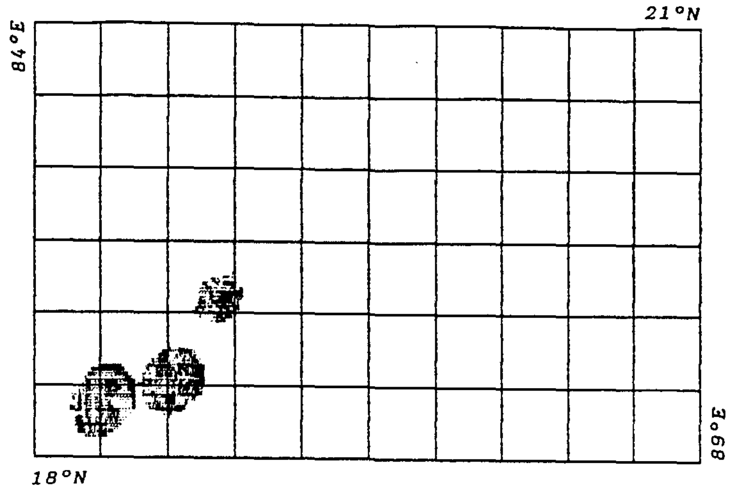


Fig. 4.22 Spatial distribution of Priacanthus during May

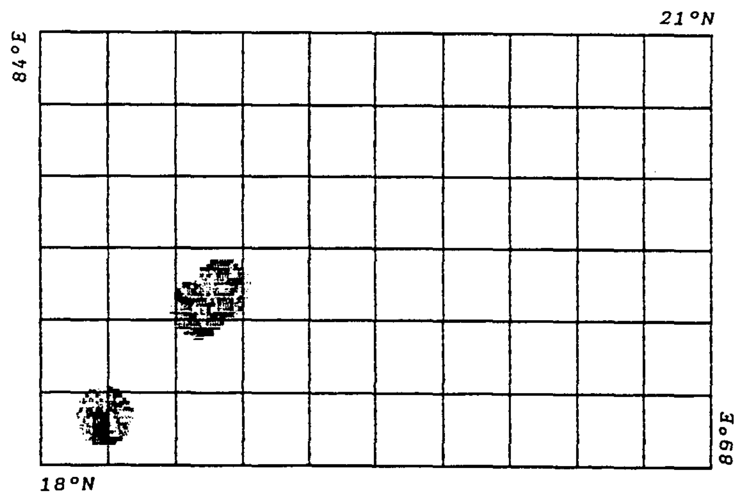


Fig. 4.23 Spatial distribution of Priacanthus during June

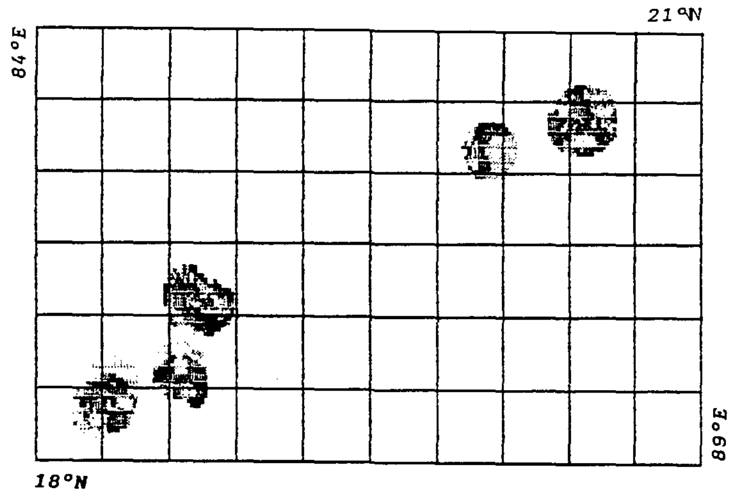


Fig. 4.24 Spatial distribution of Priacanthus during July

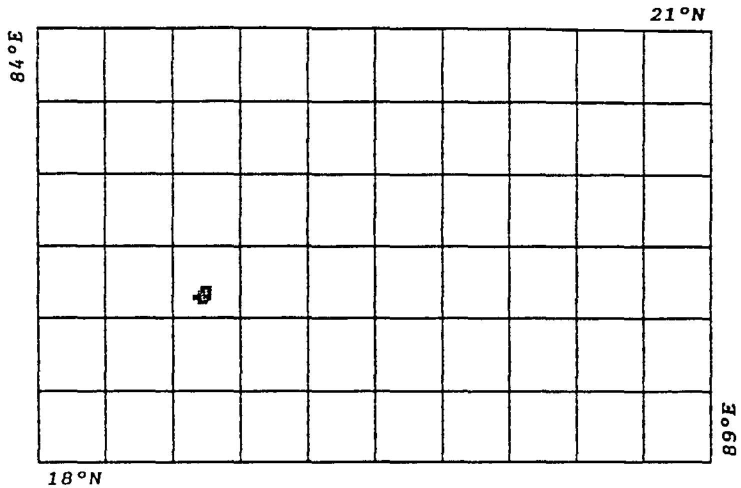


Fig. 4.25 Spatial distribution of Priacanthus during August

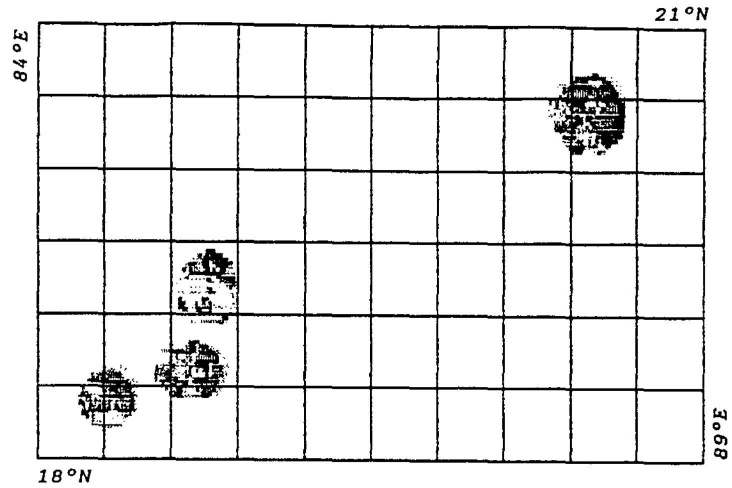


Fig. 4.26 Spatial distribution of Priacanthus during November

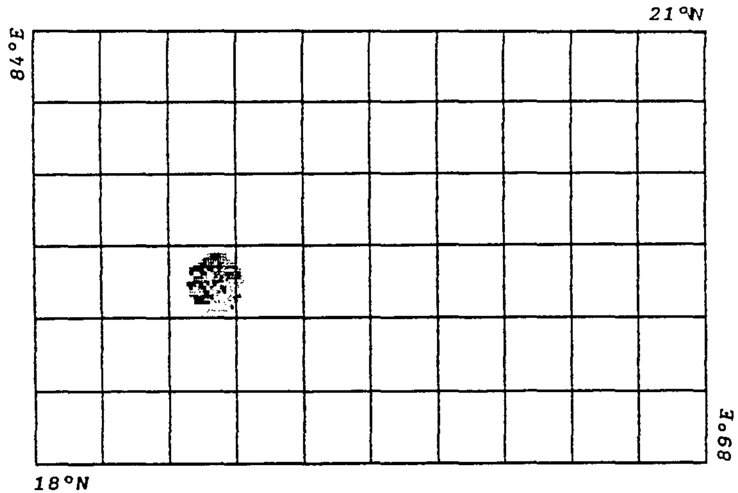


Fig. 4.27 Spatial distribution of Priacanthus during December

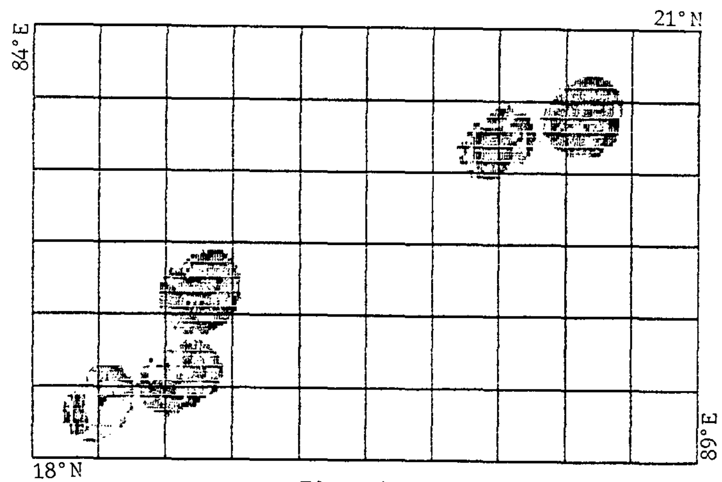


Fig. 4.28

TOTAL ANNUAL DISTRIBUTION OF PRIACANTHUS IN NORTH WEST BAY OF BENGAL

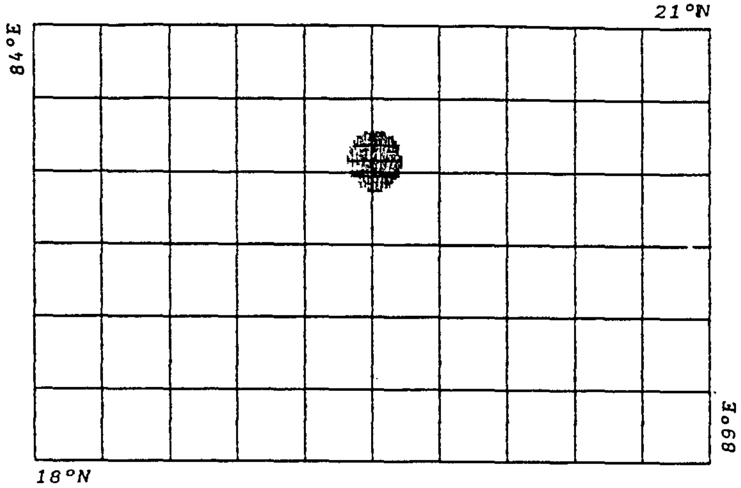


Fig. 4.29 Spatial distribution of Psenus indicus during February

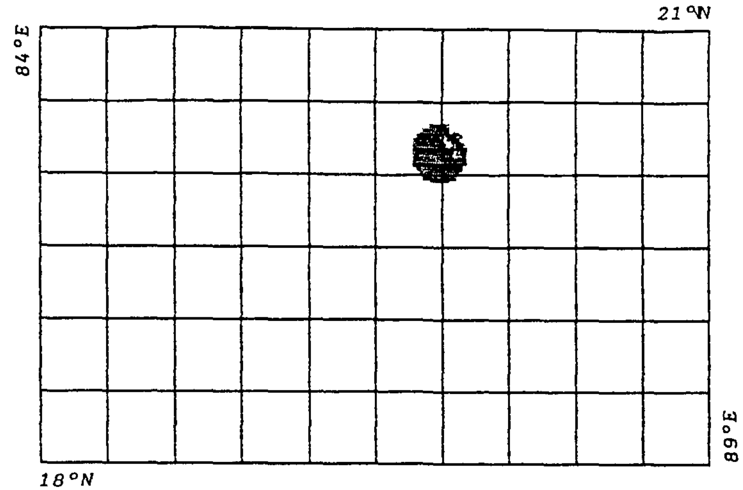


Fig. 4.30 Spatial distribution of Psenus indicus during April

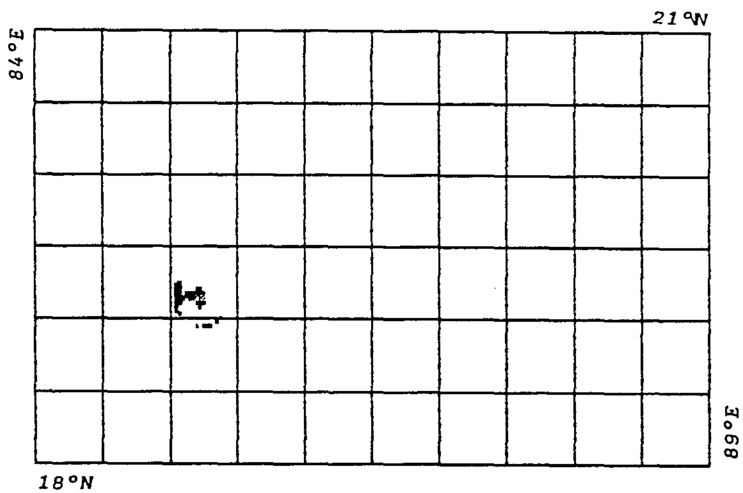


Fig. 4.31 Spatial distribution of Psenus indicus during June

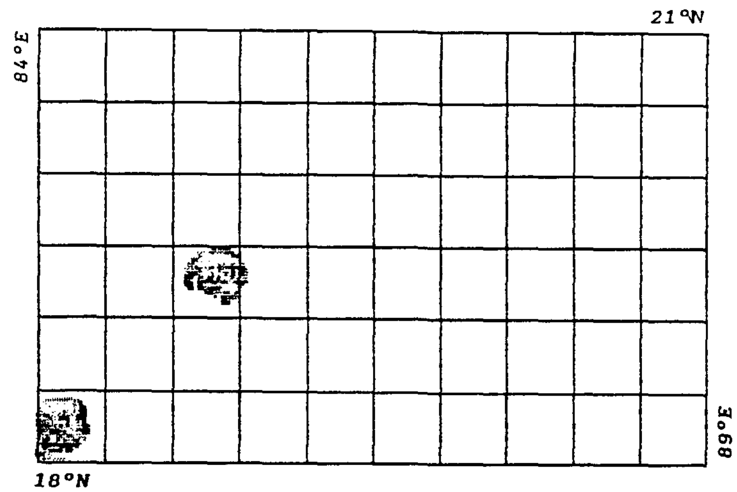


Fig. 4.32 Spatial distribution of Psenus indicus during July

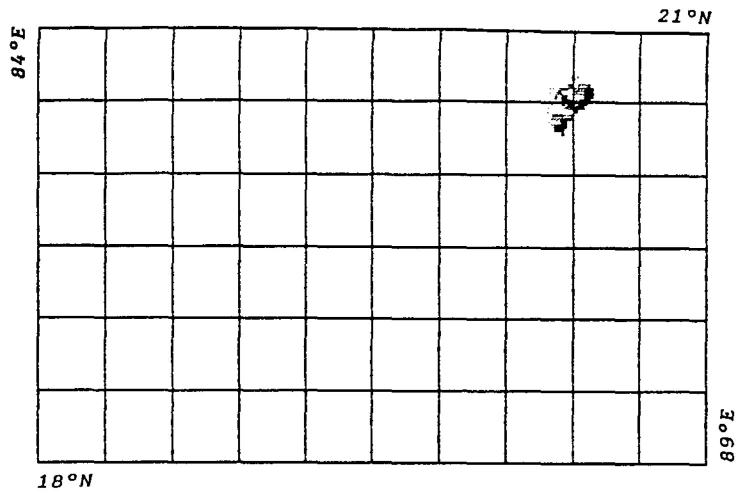


Fig. 4.33 Spatial distribution of Psenus indicus during November

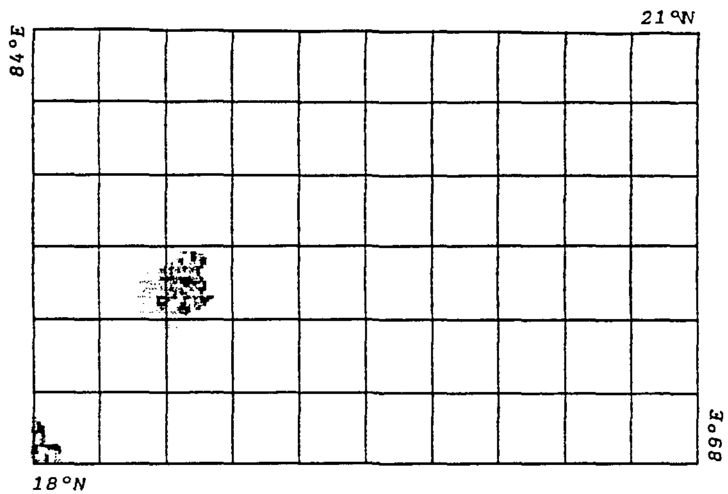


Fig. 4.34 Spatial distribution of Psenus indicus during December

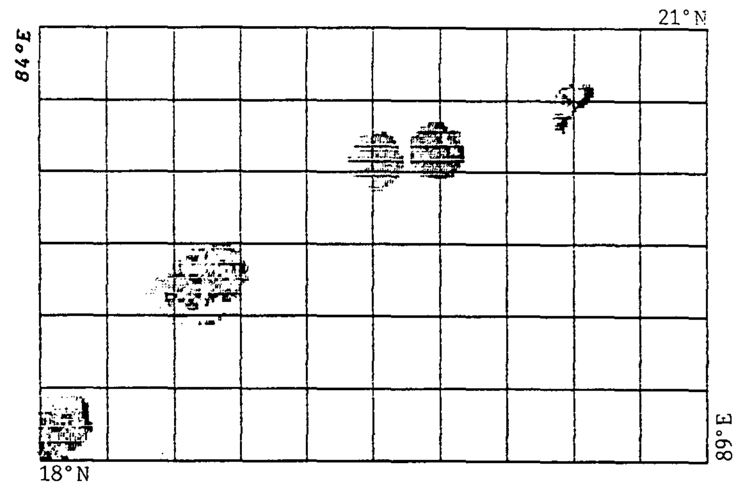


Fig. 4.35

TOTAL ANNUAL DISTRIBUTION OF P.indicus in NORTH WEST BAY OF BENGAL

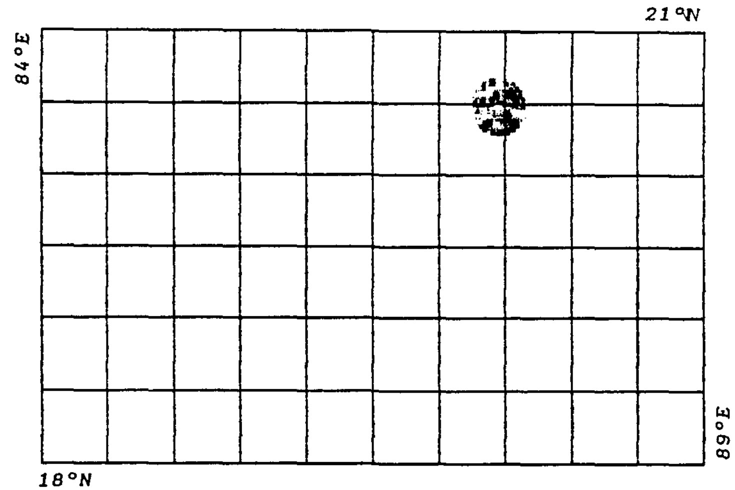


Fig. 4.36 Spatial distribution of Skate during February

4.2.5 SKATES

Skates were caught in five out of nine month catches. These were mainly found in areas between 18°-18°45'N and 84°- 84°40'E and 20°15'-20°45'N and 87°-87°40'E (Fig. 4.36-4.41) in their month-wise and total annual distribution. The catch ranged from 0-232kg with an average catch of 56.7kg/month (Table 4.1). Skates were caught in the depth range of 36-60 meters.

4.2.6 RAYS

Rays were caught in seven out of nine month fish catches. Rays were mainly found in the areas between 18°-18°25'N and 84°-84°25'E; 18°50'-19°15'N and 84°15'-84°45'E' 19°10'- 19°30'N and 85°-85°25°; 19°20'-19°45'N and 86°-86°30'E and 19°50'-20°40'N and 86°50'-87°30'E (Fig. 4.42-4.49) in their month-wise and total annual distribution. The catch ranged from 0-235kg with an average catch of 69.6kg/month (Table 4.1). Rays were caught in the depth range of 36-60 meters.

4.2.7 EELS

Eels were caught in five out of nine month catches. These were mainly found in the areas 18°-18°10'N and 84°05'-84°50'-85°35'E; 19°15'-19°40'N and 85°50'-86°20'E and 19°50'-20°10'N and 86°50'-87°05'E (Fig. 4.50-4.54) in their month-wise and total annual distribution. The catch ranged from 0-11kg with an average catch of 3.3kg/month (Table 4.1). Eels were caught in the depth range of 40 to 60 meters.

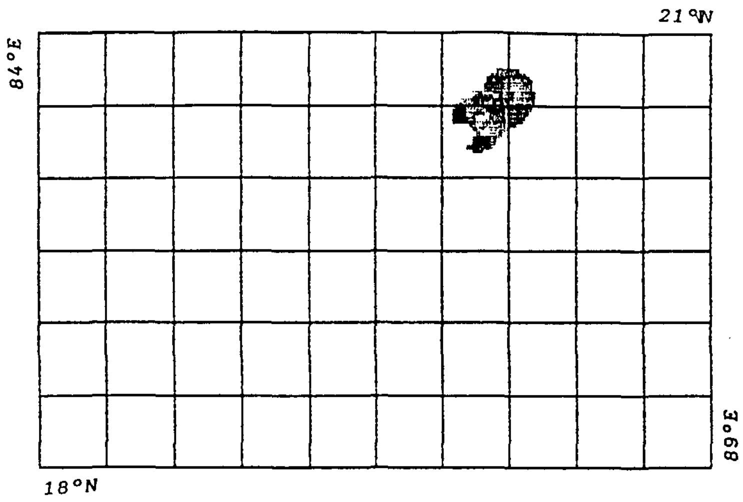


Fig. 4.37 Spatial distribution of Skate during April

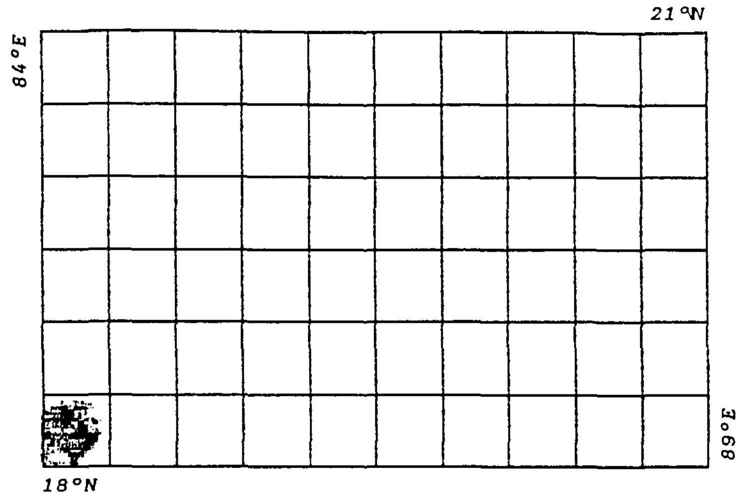


Fig. 4.38 Spatial distribution of Skate during May

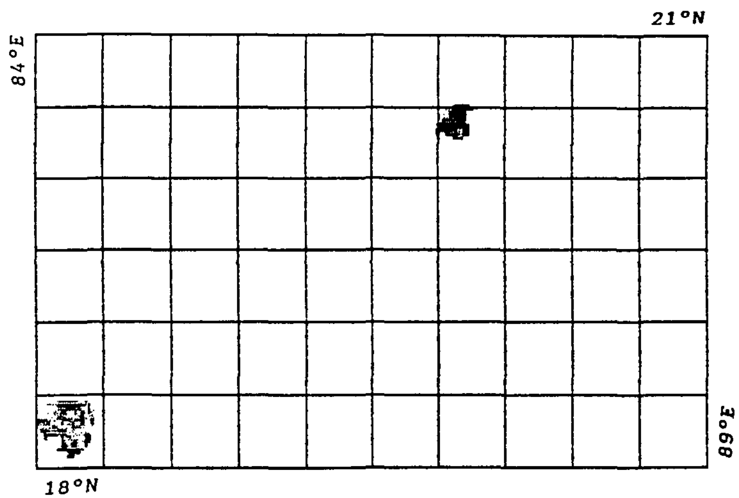


Fig. 4.39 Spatial distribution of Skate during November

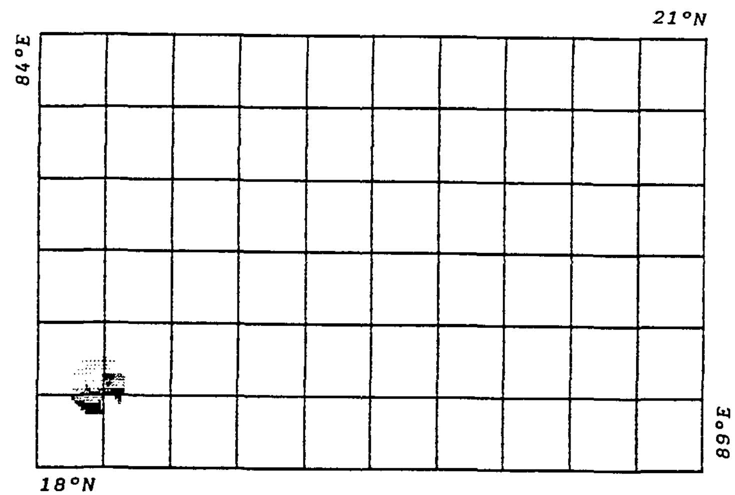


Fig. 4.40 Spatial distribution of Skate during December

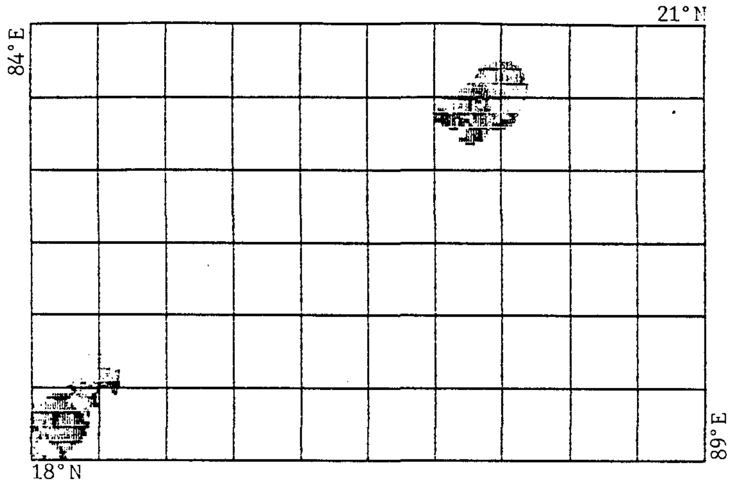


Fig. 4.41

TOTAL ANNUAL DISTRIBUTION OF SKATE IN NORTH WEST BAY OF BENGAL

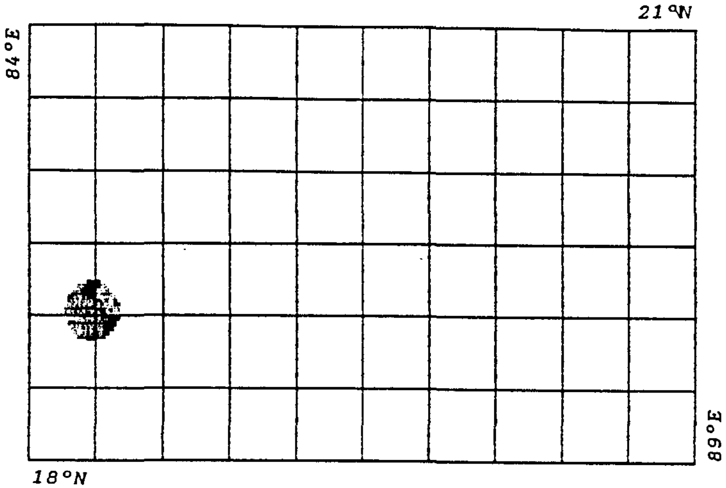


Fig. 4.42 Spatial distribution of Ray during March

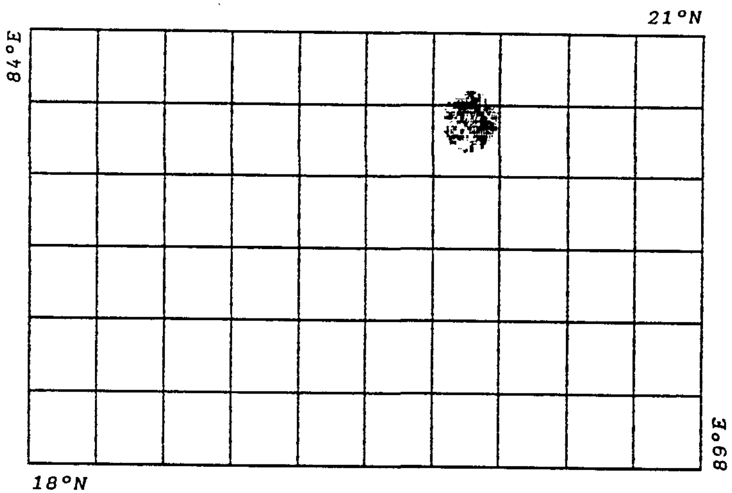


Fig. 4.43 Spatial distribution of Ray during April

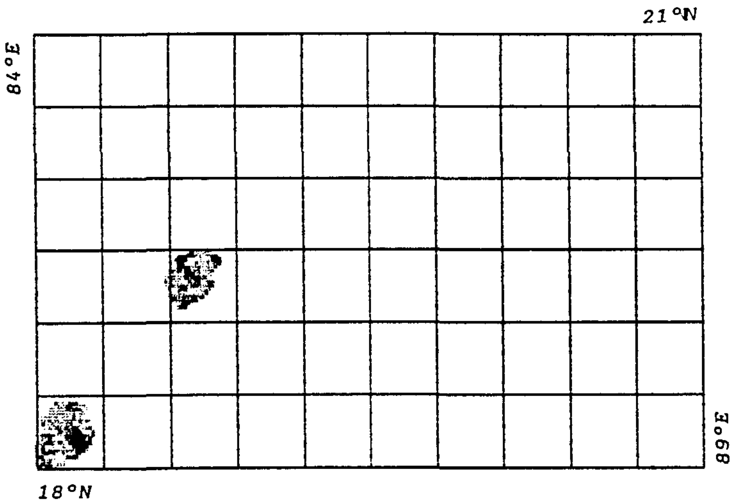


Fig. 4.44 Spatial distribution of Ray during May

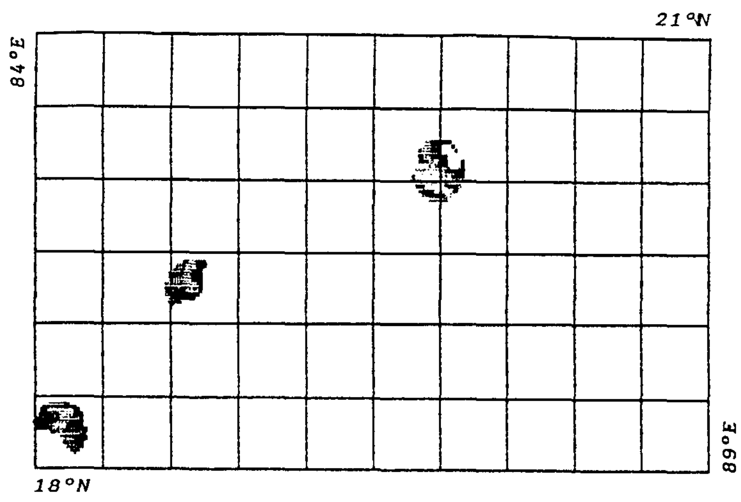


Fig. 4.45 Spatial distribution of Ray during June

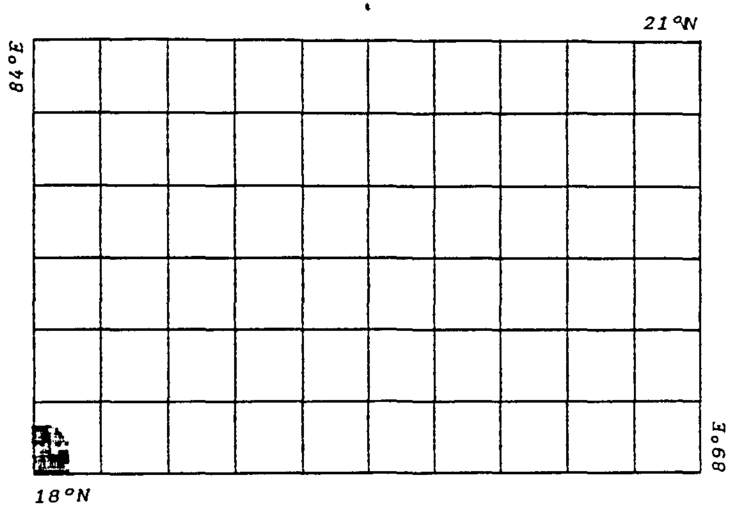


Fig. 4.46 Spatial distribution of Ray during July

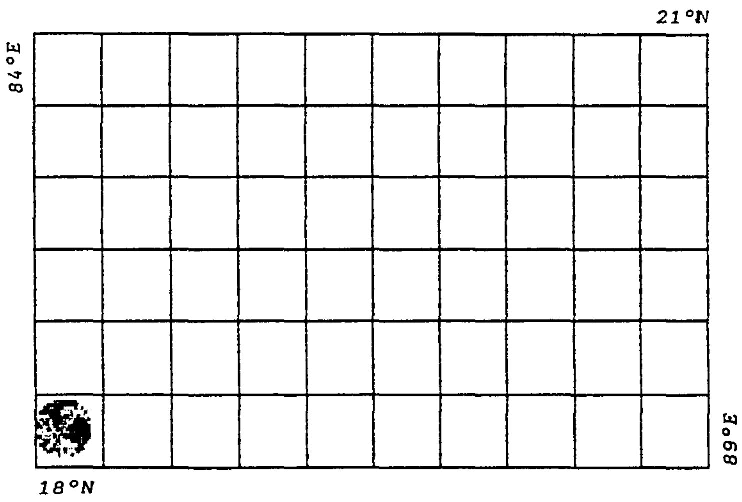


Fig. 4.47 Spatial distribution of Ray during November

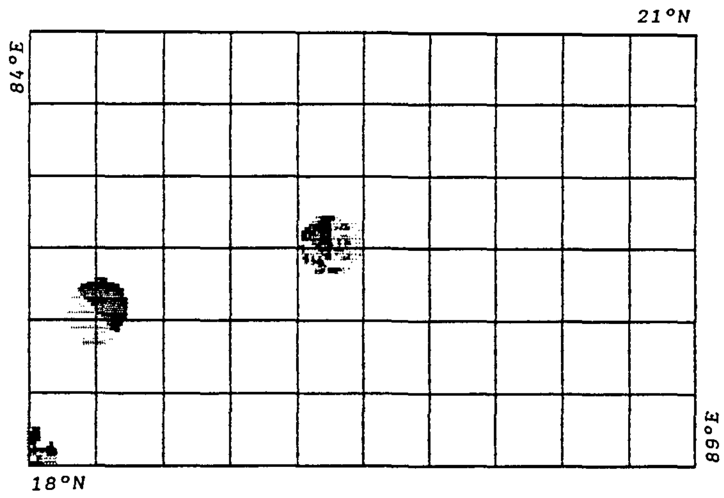


Fig. 4.48 Spatial distribution of Ray during December

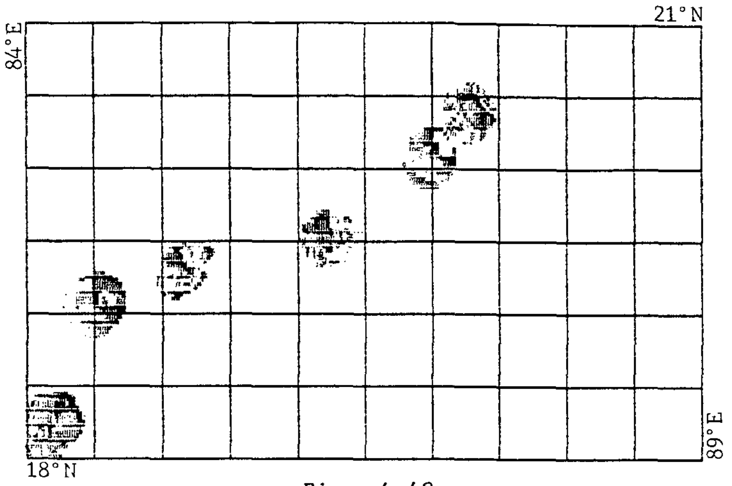


Fig. 4.49

TOTAL ANNUAL DISTRIBUTION OF RAYS IN NORTH WEST BAY OF BENGAL

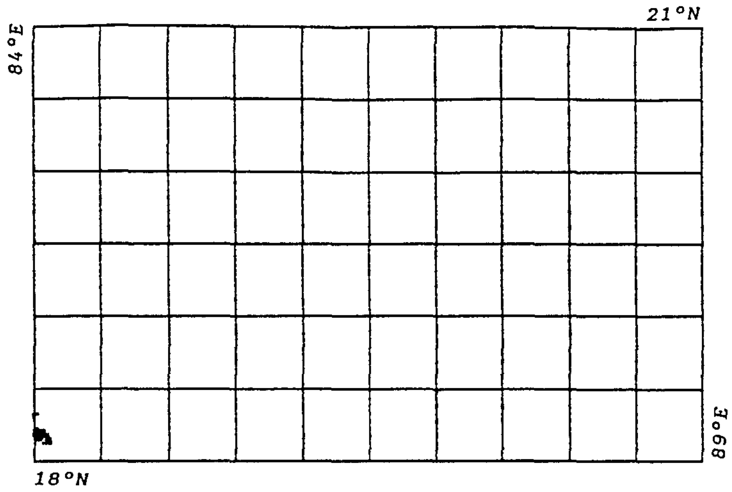


Fig. 4.50 Spatial distribution of Eel during May

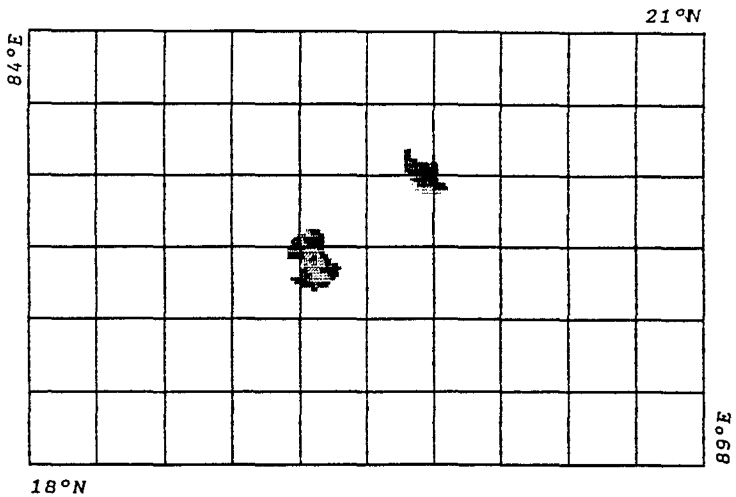


Fig. 4.51 Spatial distribution of Eel during June

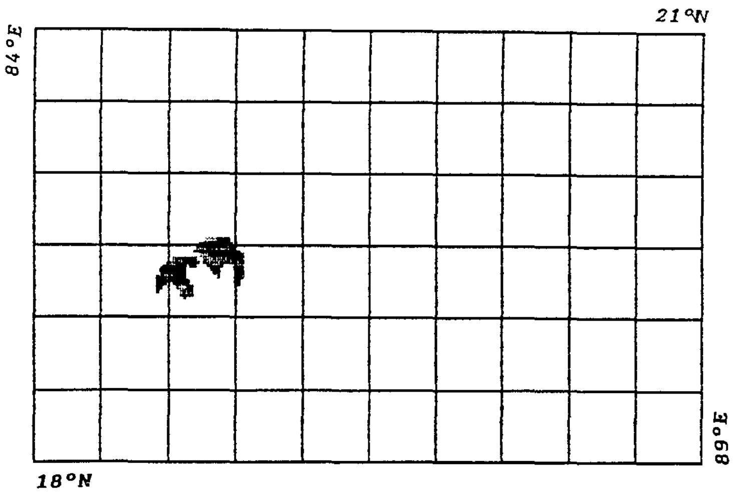


Fig. 4.52 Spatial distribution of Eel during August

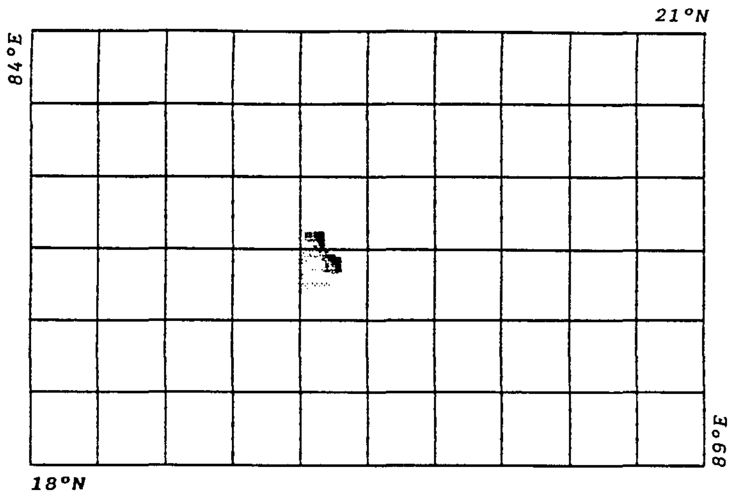


Fig. 4.53 Spatial distribution of Eel during December

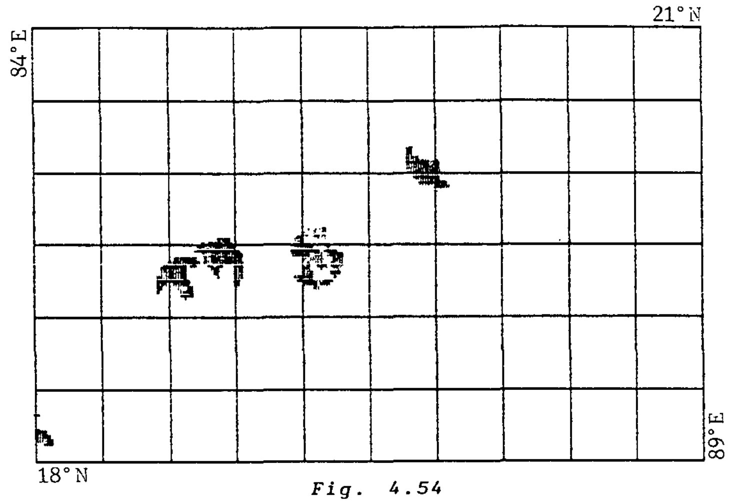


Fig. 4.54

TOTAL ANNUAL DISTRIBUTION OF EEL IN NORTH WEST BAY OF BENGAL

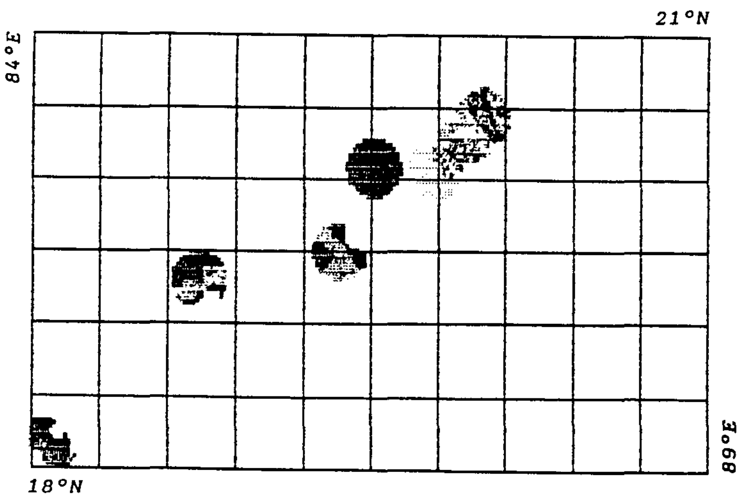


Fig. 4.55 Spatial distribution of Catfish during February

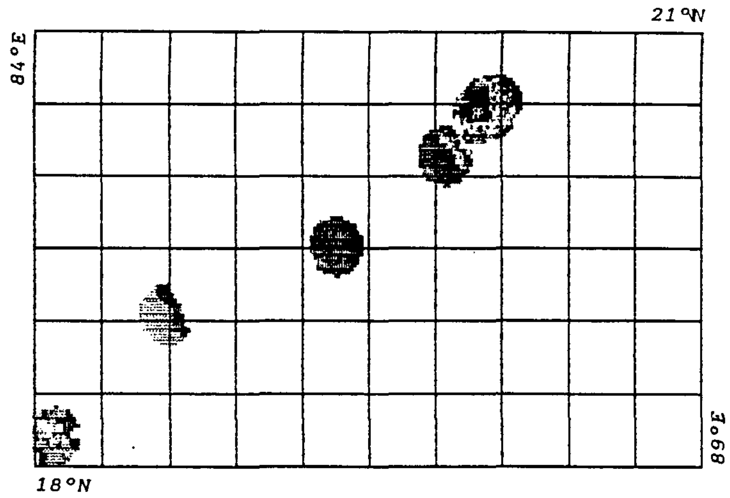


Fig. 4.56 Spatial distribution of Catfish during March

4.2.8 CATFISHES

Catfishes were caught in all the nine month catches. These were mainly found in areas between 18°-18°45'N and 84°-84°40'E; 18°50'-19°35'N and 84°45'-85°40'E; 19°10'- 19°45'N and 85°50'-86°30'E and 19°50-20°45'N and 86°20'-88°05'E (Fig. 4.55-4.64) in their month-wise and total annual distribution. The catch ranged from 133-2965 kg with an average catch of 1083.7 kg/month (Table 4.1). Catfishes were caught in the depth range of 30-70 meters.

4.2.9 RIBBON FISHES

Ribbon fishes were caught in seven out of nine month catch es. These were mainly found in areas between 18°-18°45'N and 84°-84°40'E; 19°00'-19°30'N and 84°55'-85°35'E; 19°10'-. 19°45'N and 86°50'-86°30'E; 19°55' -20°20'N and 86°50'- 87°15'E and 20°20'-20°45' N and 87°20'-88°20'E. (Fig. 4.65- 4.72) in their month-wise and total annual distribution. The catch ranged from 0-443kg with an average catch of 109kg/month (Table 4.1). Ribbon fishes were caught in the depth range of 40- 70 meters.

4.2.10 KARKARAS

Karkaras were caught in eight out of nine month catches. These were mainly found in areas between 18°-18°45'N and 84°-84°40'E; 18°50'-19°35'N and 84°20-85°35'E; 19°10'-19°45' N

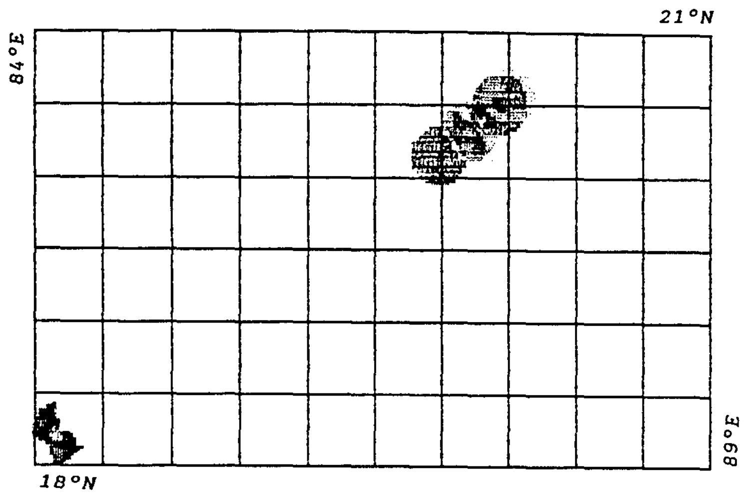


Fig. 4.57 Spatial distribution of Catfish during April

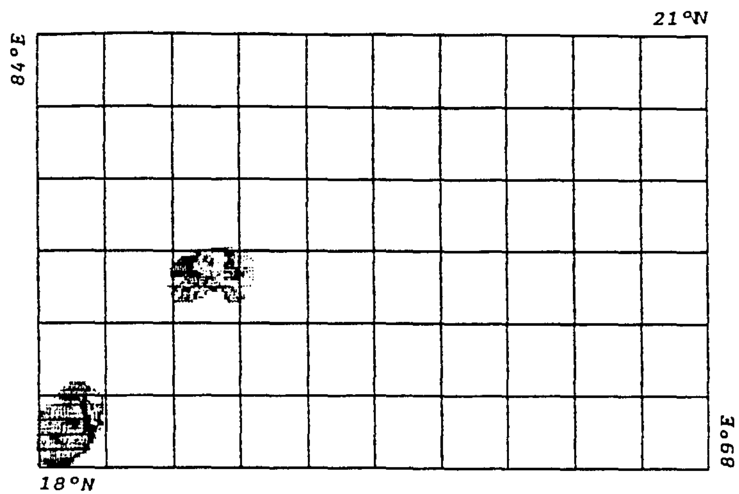


Fig. 4.58 Spatial distribution of Catfish during May

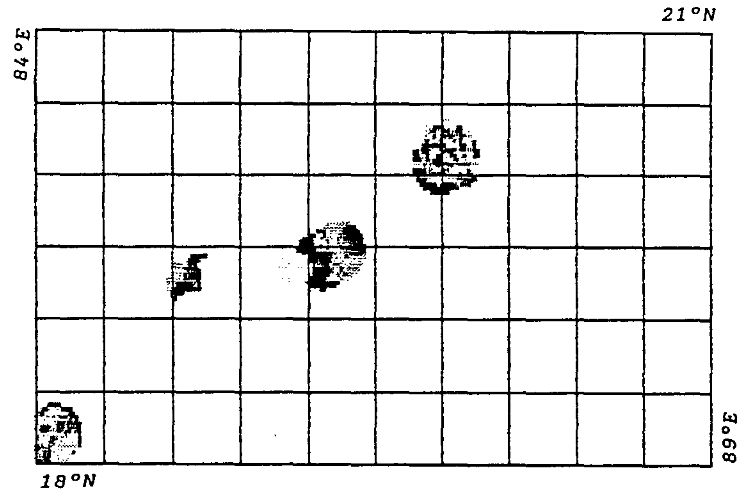


Fig. 4.59 Spatial distribution of Catfish during June

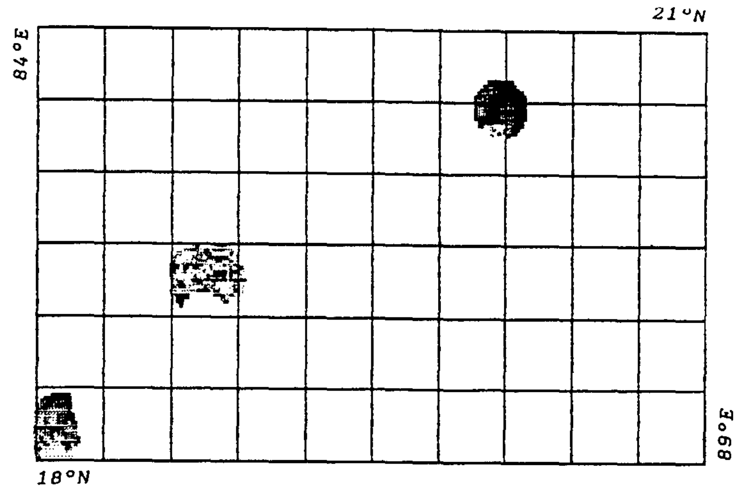


Fig. 4.60 Spatial distribution of Catfish during July

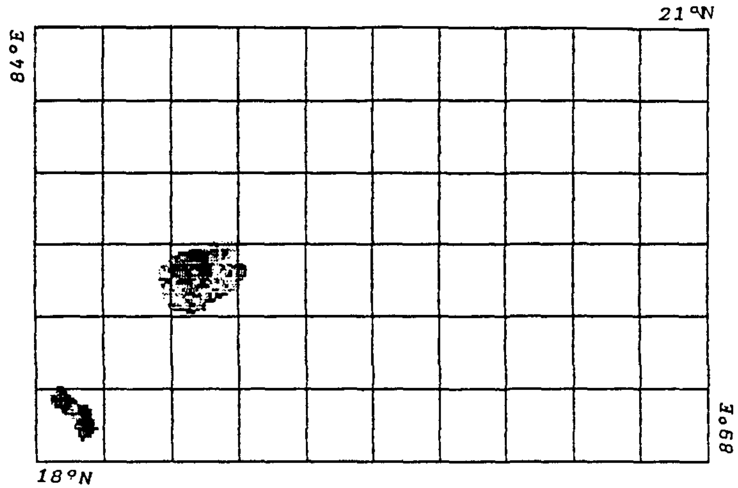


Fig. 4.61 Spatial distribution of Catfish during August

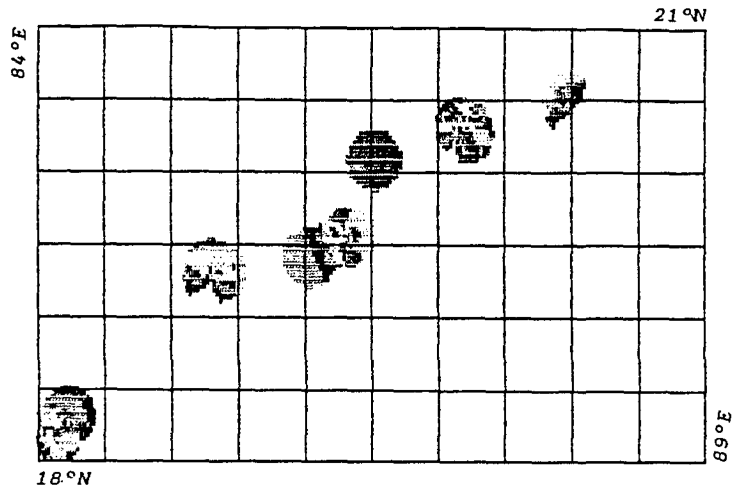


Fig. 4.62 Spatial distribution of Catfish during November

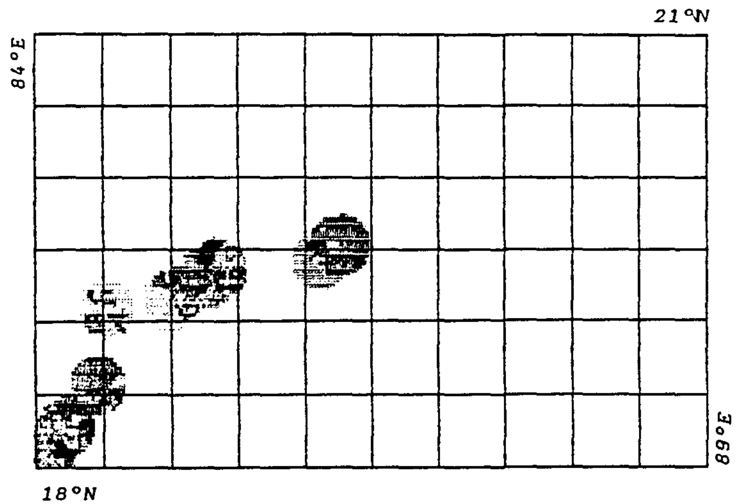


Fig. 4.63 Spatial distribution of Catfish during December

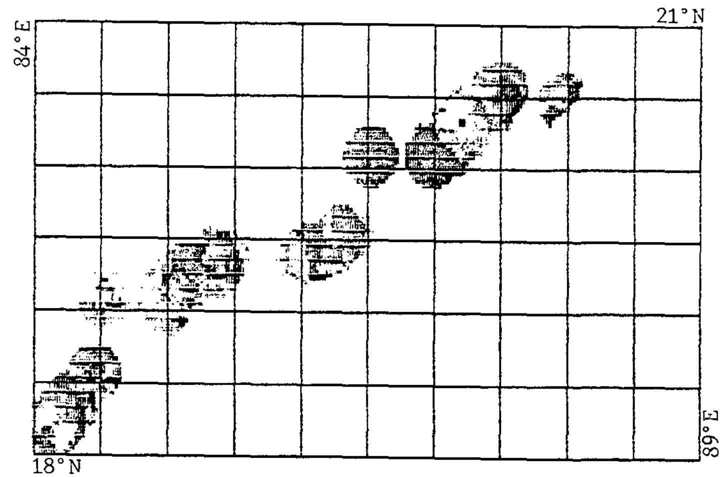


Fig. 4.64

TOTAL ANNUAL DISTRIBUTION OF CAT FISH IN NORTH WEST BAY OF BENGAL

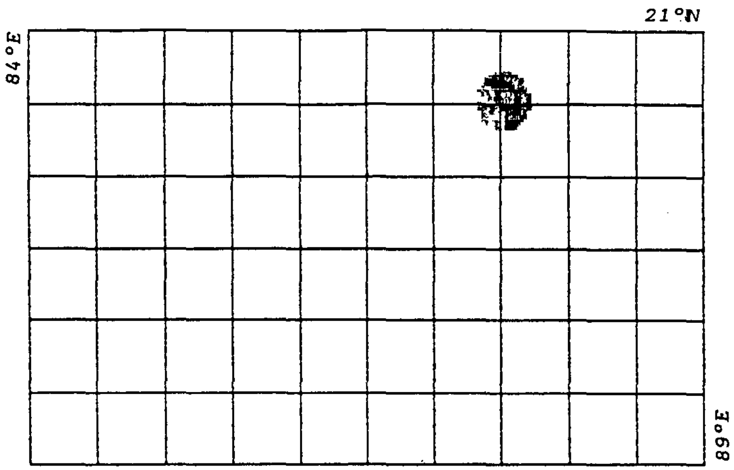


Fig. 4.65 Spatial distribution of Ribbon fish during February

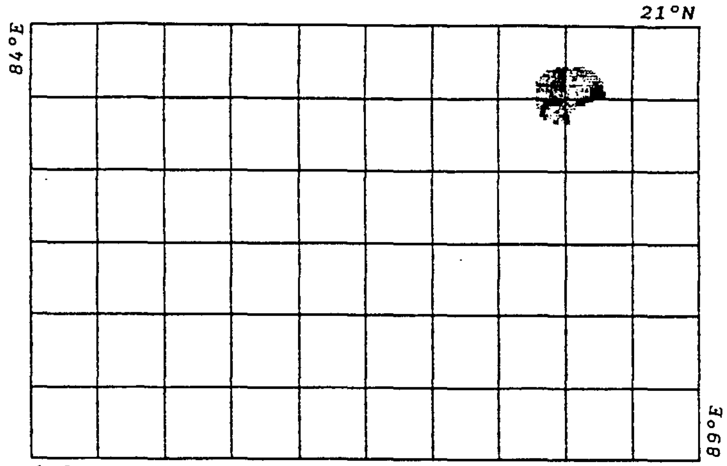


Fig. 4.66 Spatial distribution of Ribbon fish during April

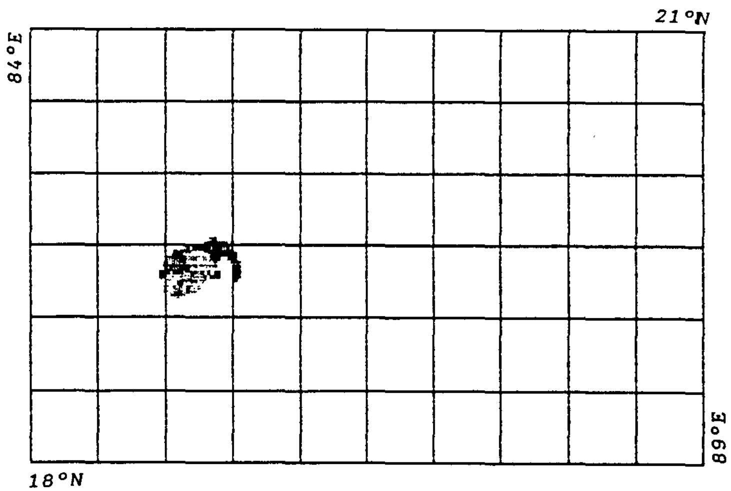


Fig. 4.67 Spatial distribution of Ribbon fish during May

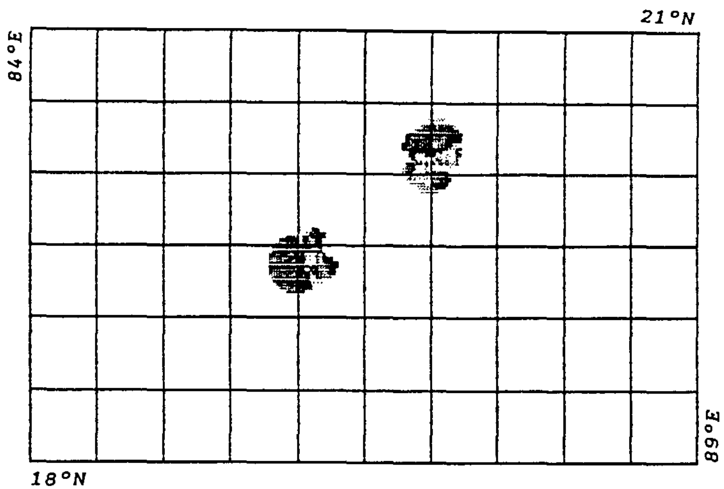


Fig. 4.68 Spatial distribution of Ribbon fish during June

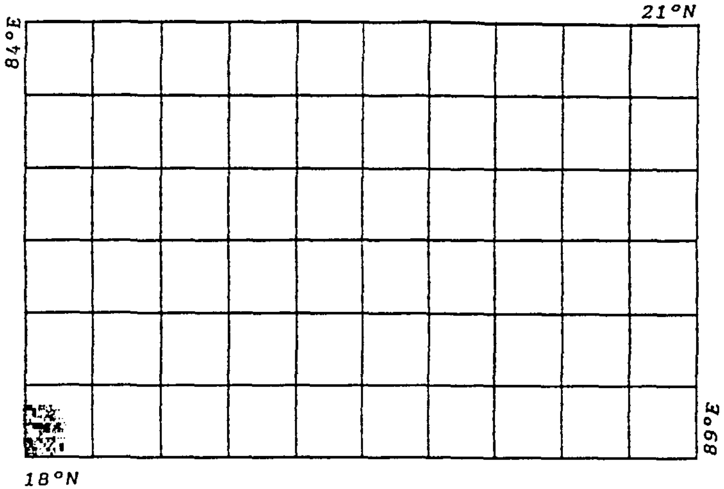


Fig. 4.69 Spatial distribution of Ribbon fish during July

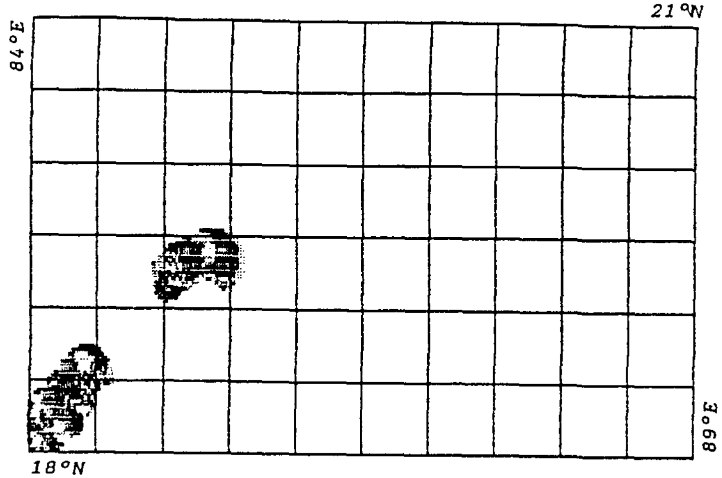


Fig. 4.70 Spatial distribution of Ribbon fish during August

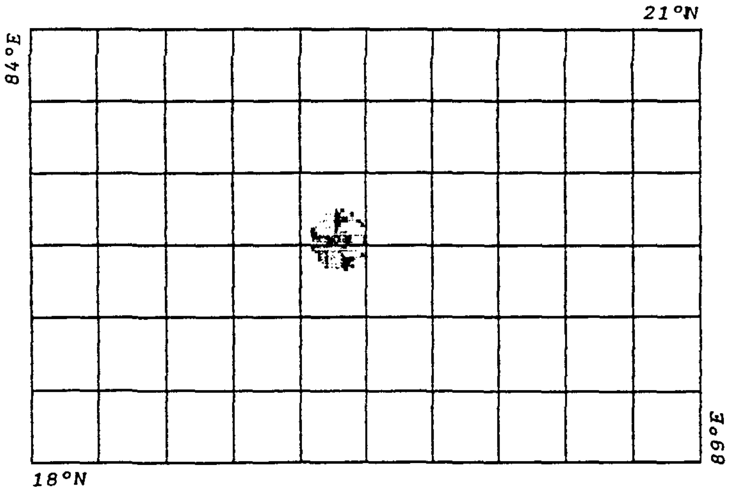


Fig. 4.71 Spatial distribution of Ribbon fish during December

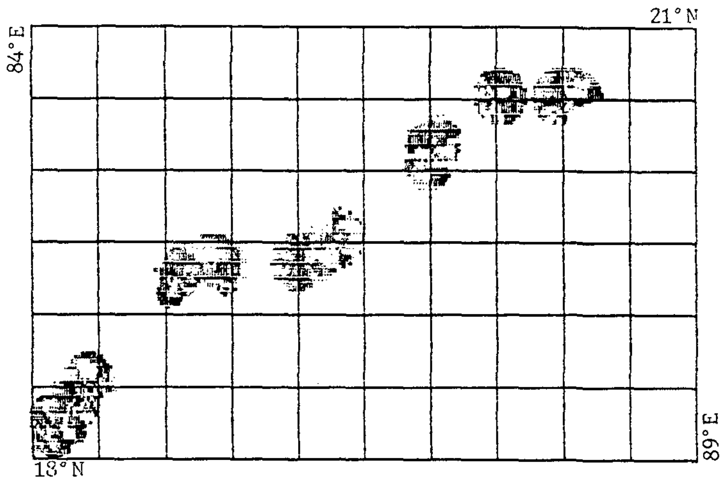


Fig 4.72

TOTAL ANNUAL DISTRIBUTION OF RIBBON FISH IN NORTH WEST BAY OF BENGAL

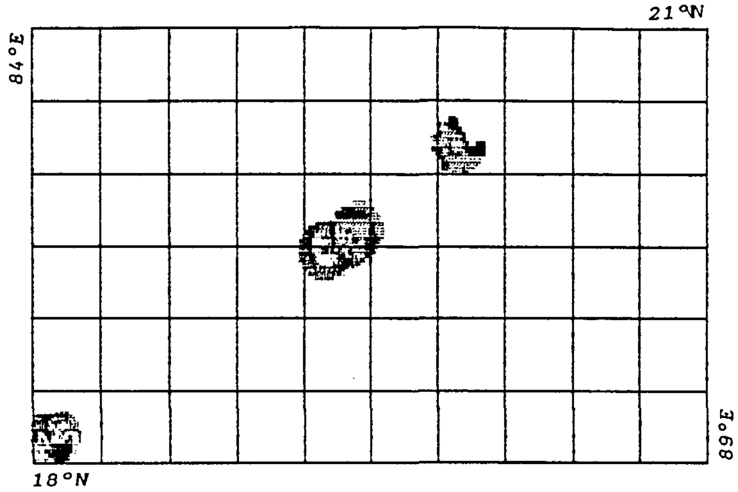


Fig. 4.73 Spatial distribution of Karkara during February

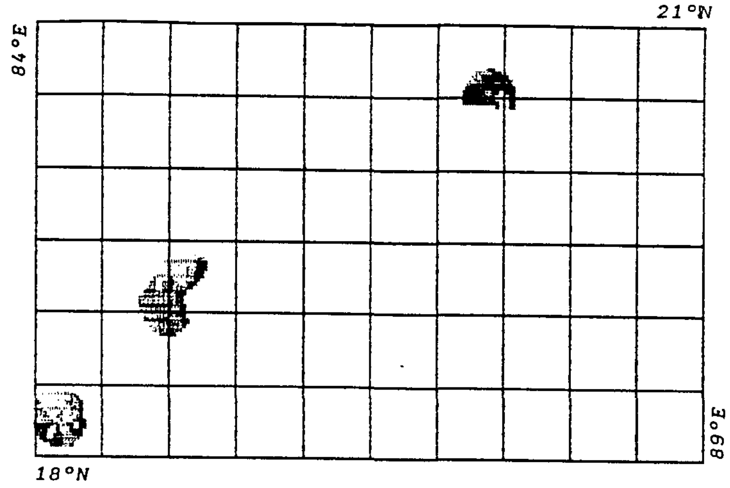


Fig. 4.74 Spatial distribution of Karkara during March

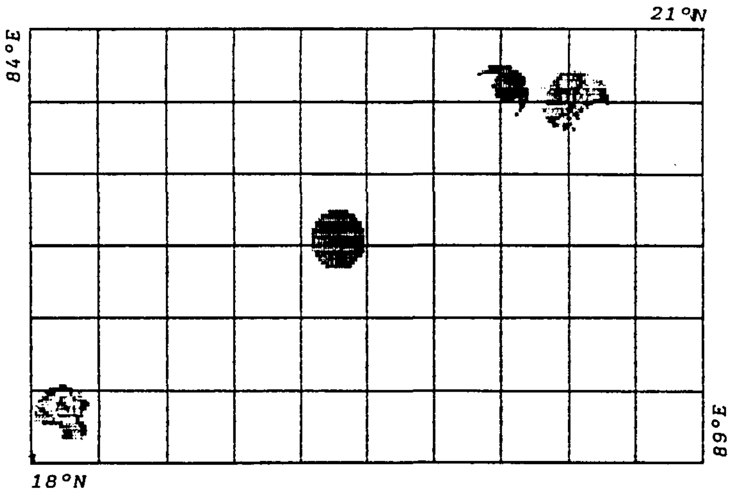


Fig. 4.75 Spatial distribution of Karkara during April

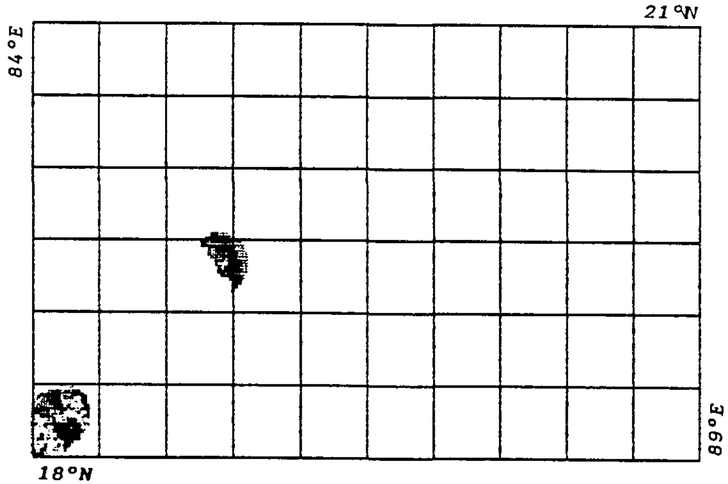


Fig. 4.76 Spatial distribution of Karkara during May

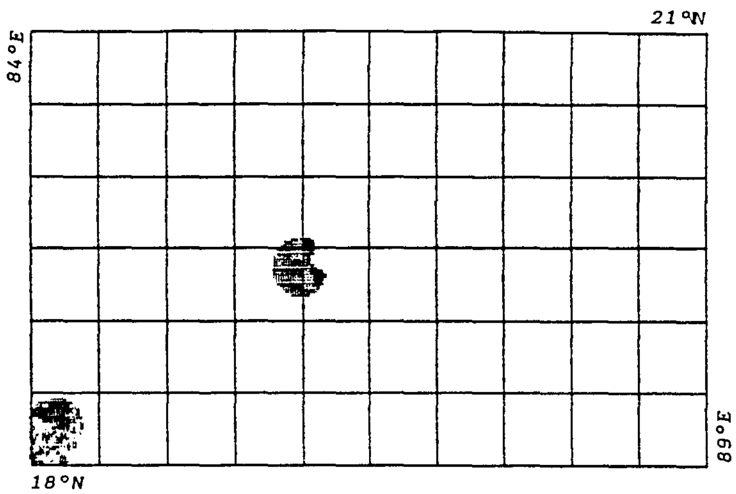


Fig. 4.77 Spatial distribution of Karkara during June

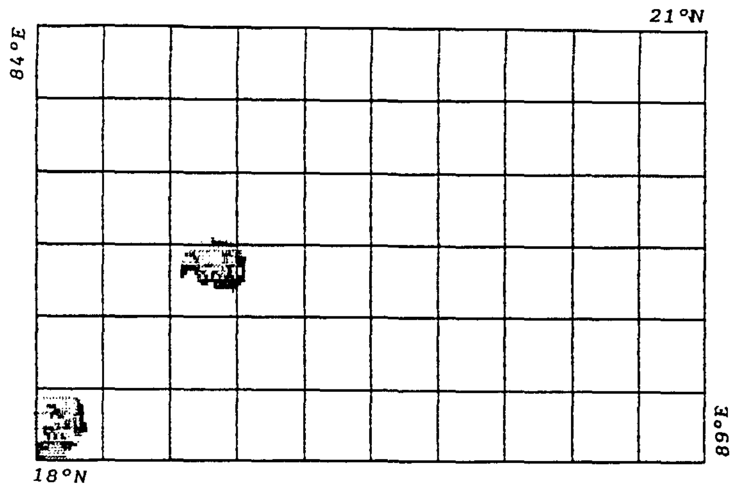


Fig. 4.78 Spatial distribution of Karkara during July

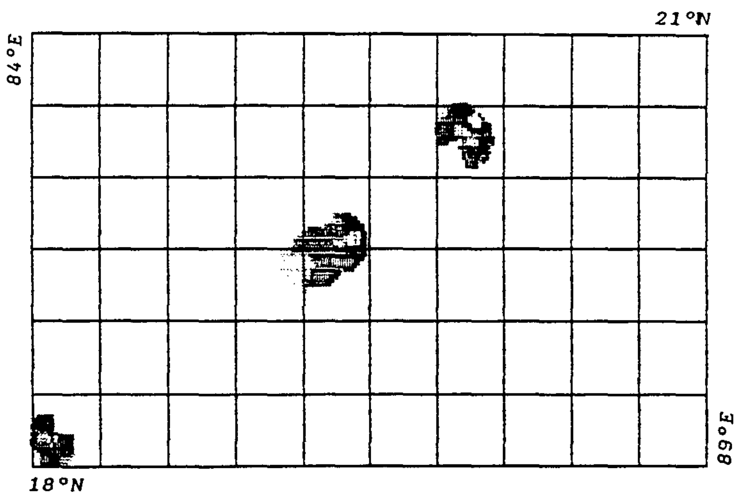


Fig. 4.79 Spatial distribution of Karkara during November

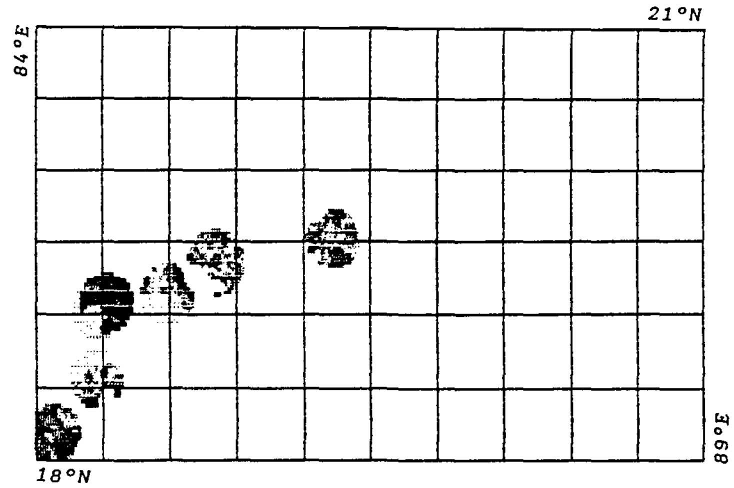


Fig. 4.80 Spatial distribution of Karkara during December

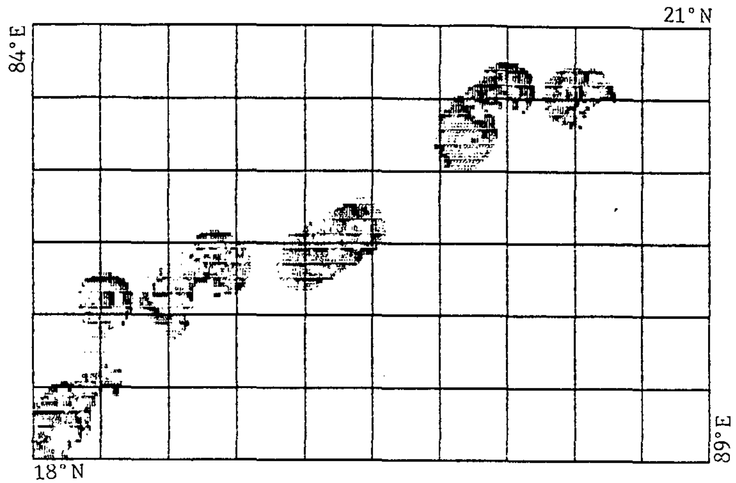


Fig. 4.81

TOTAL ANNUAL DISTRIBUTION OF KARKARA IN
NORTH WEST BAY OF BENGAL

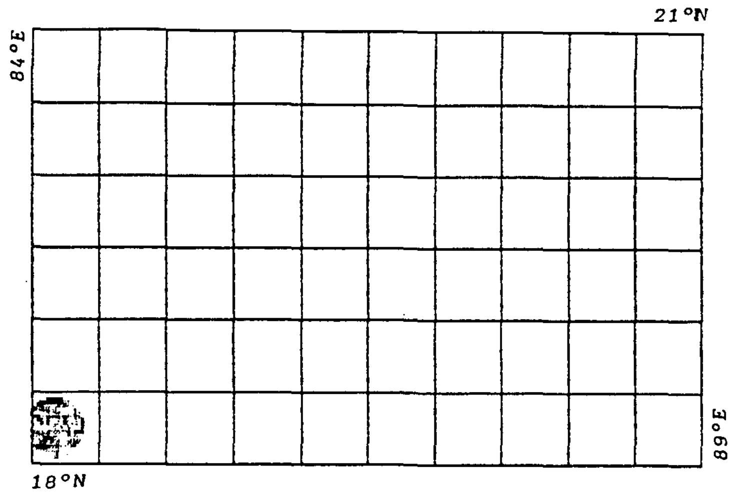


Fig. 4.82 Spatial distribution of Sea Bream during March

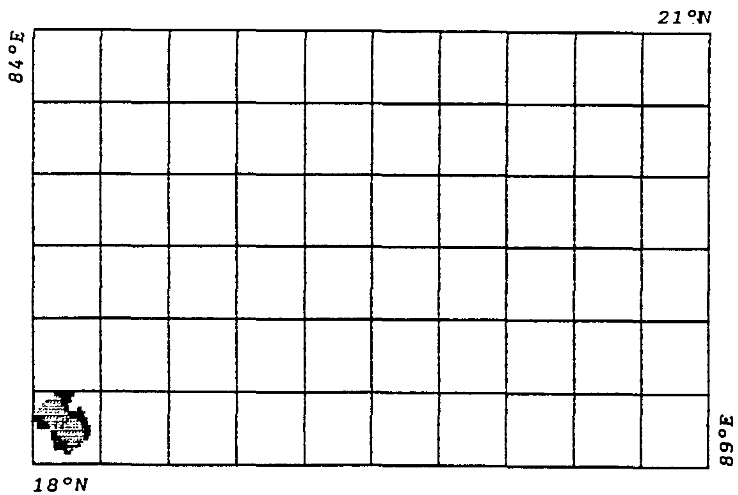


Fig. 4.83 Spatial distribution of Sea Bream during May

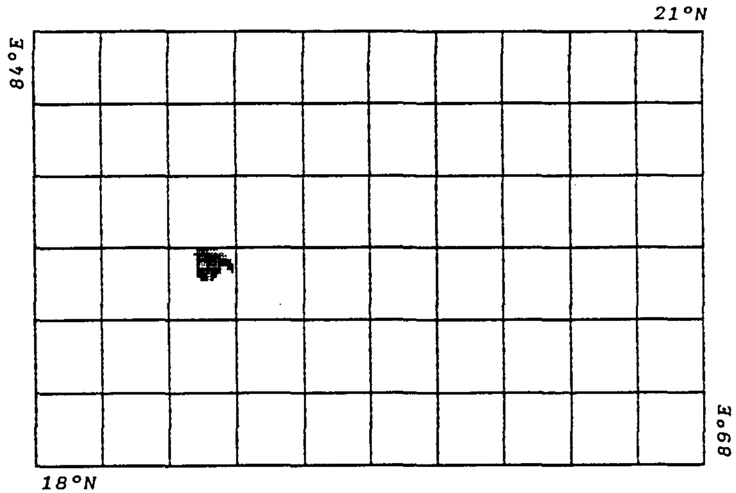


Fig. 4.84 Spatial distribution of Sea Bream during June

and 85°50'-86°35'E and 20°-20°45'N and 87°-88°15'E (Fig. 4.73-4.81) in their month-wise and annual distribution. The catch ranged from 40-545kg with an average catch of 173kg/month (Table 4.1). Karkaras were caught in the depth range of 30-70 meters.

4.2.11 SEA BREAMS

Sea breams were caught in five out of the nine month catches. They were mainly found in areas between 18°-18°30'N and 84°-84°25'E; 19°15'-19°30'N and 85015'-85°30'E and 19°10'-19°35'N and 85°15'-85°30'E and 19°10'-19°35'N and 85°50'-86°15'E (Fig. 4.82-4.87) in their month-wise and total annual distribution. The catch ranged from 0-31kg with an average catch of 6kg/month (Table 4.1). Sea breams were caught in a depth range of 30-60 meters.

4.2.12 POMFRETS

Pomfrets were caught in all the nine month catches. They were mainly caught in areas between 18°-18°45'N and 84°-84°40'E; 18°50'-19°45'N and 84°20'-84°45' E; 19°-19°30'N and 84°55'-85°35' E; 19°10'-19°45'N and 85°50'-86°30'E and 19°50'-20°40'N and 86°20'-87°35'E (Fig. 4.88-4.97) in their month-wise and total annual distribution. The catch ranged from 1-284kg with an average catch of 148.1kg/month (Table 4.1). Pomfrets were caught in the depth range of 30-70 meters.

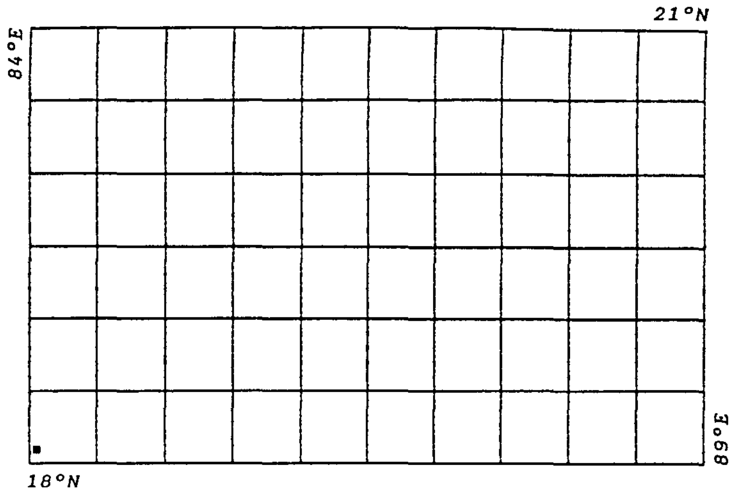


Fig. 4.85 Spatial distribution of Sea Bream during July

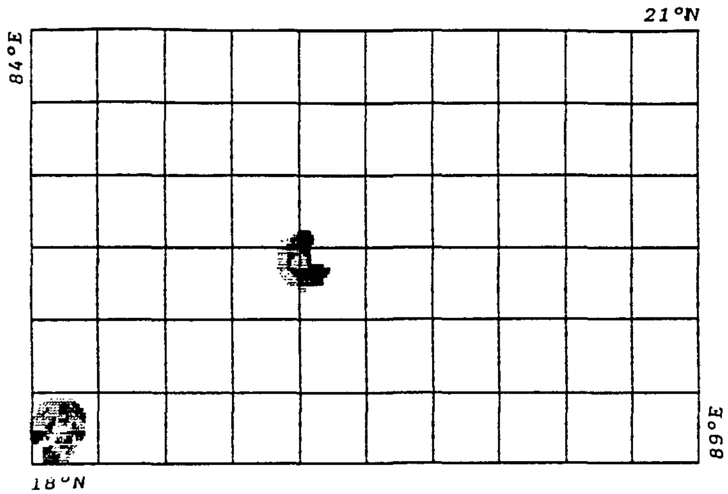


Fig. 4.86 Spatial distribution of Sea Bream during November

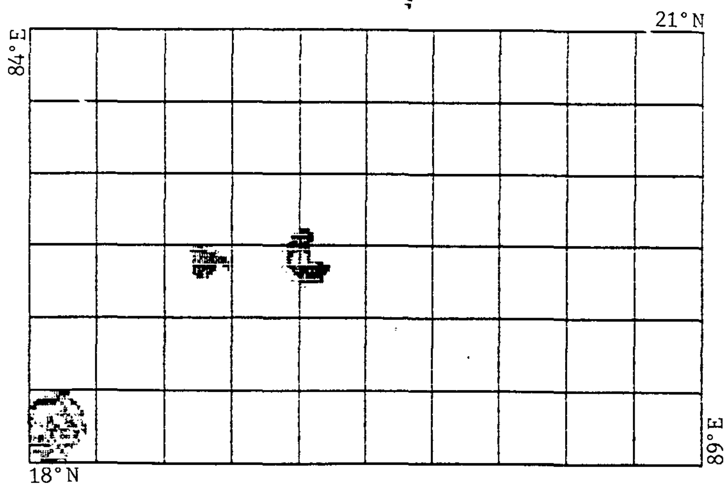


Fig. 4.87

TOTAL ANNUAL DISTRIBUTION OF SEA BREAM IN NORTH WEST BAY OF BENGAL

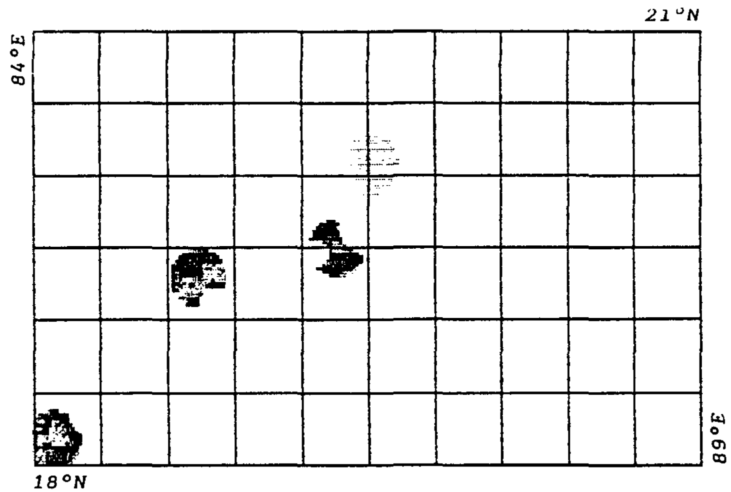


Fig. 4.88 Spatial distribution of Pomfret during February

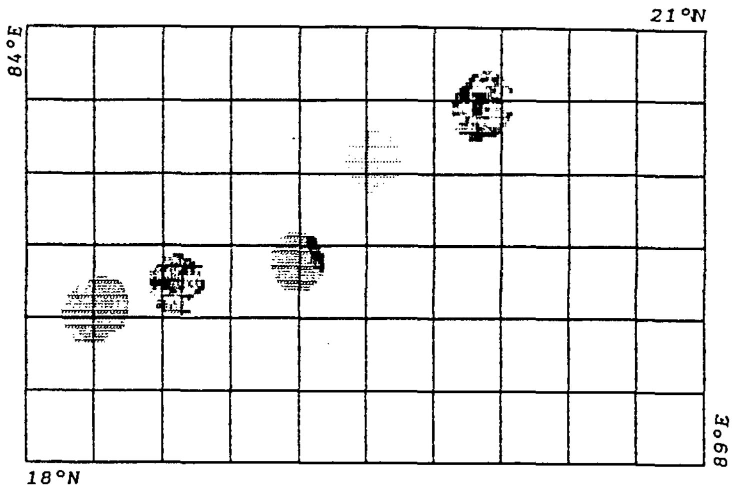


Fig. 4.89 Spatial distribution of Pomfret during March

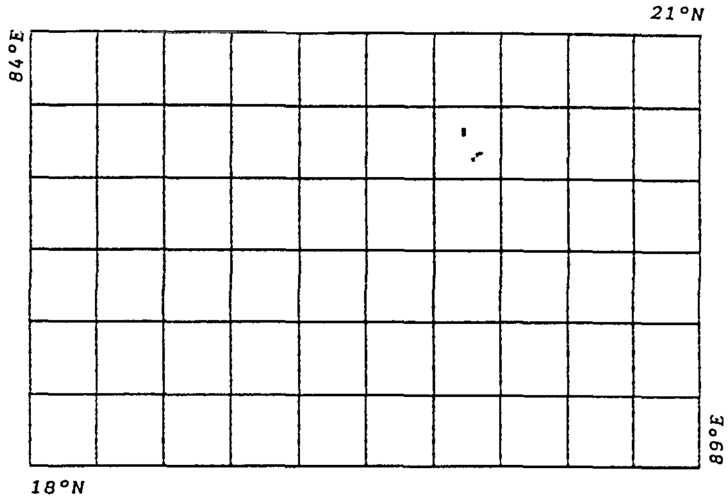


Fig. 4.90 Spatial distribution of Pomfret during April

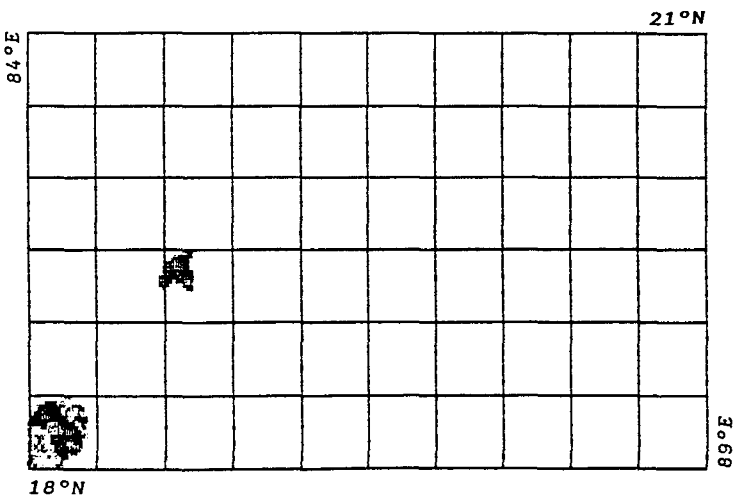


Fig. 4.91 Spatial distribution of Pomfret during May

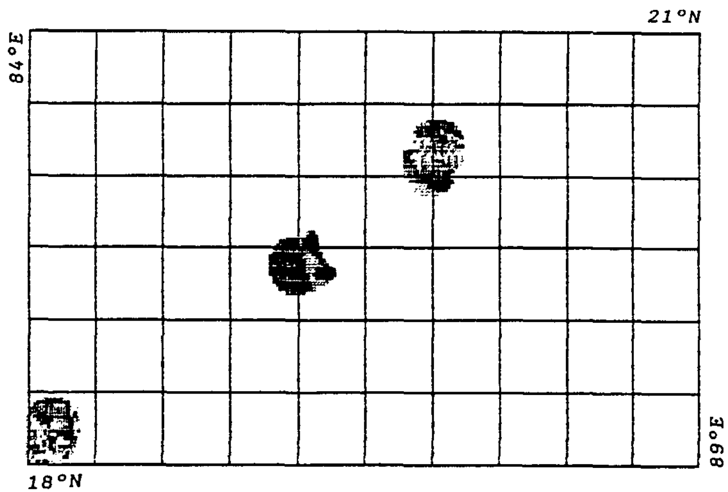


Fig. 4.92 Spatial distribution of Pomfret during June

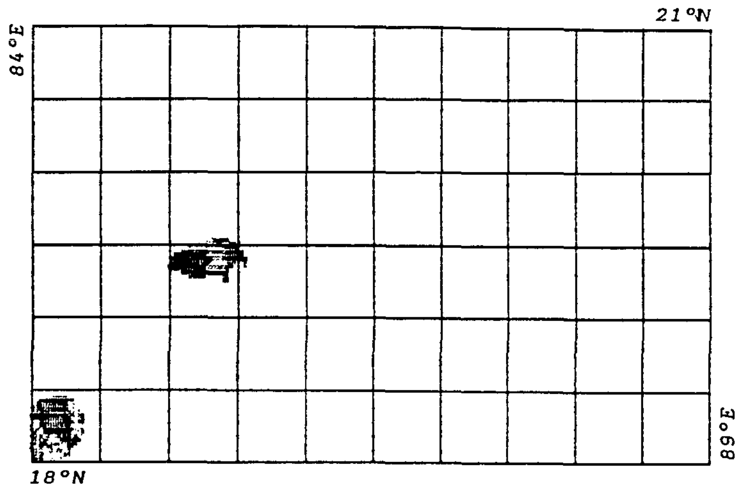


Fig. 4.93 Spatial distribution of Pomfret during July

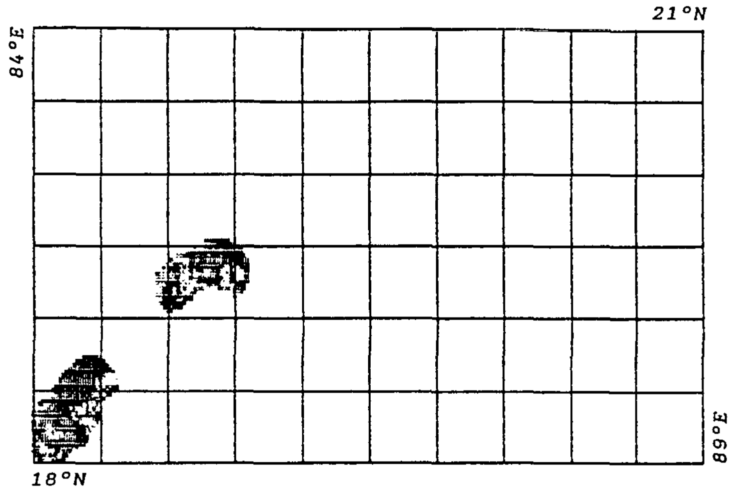


Fig. 4.94 Spatial distribution of Pomfret during August

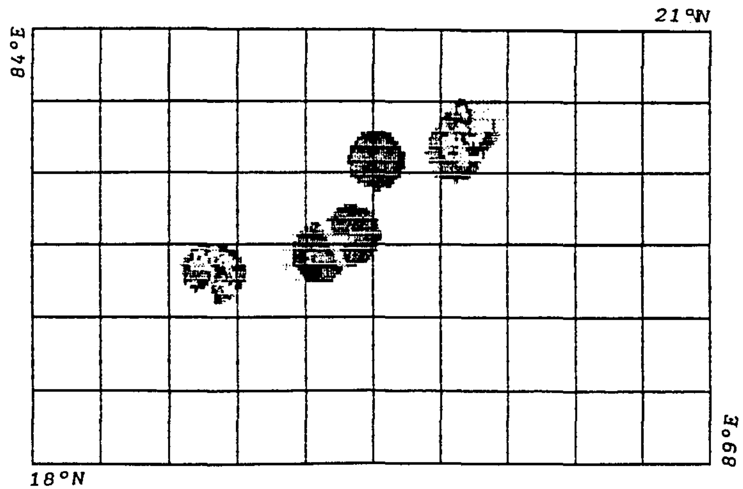


Fig. 4.95 Spatial distribution of Pomfret during November

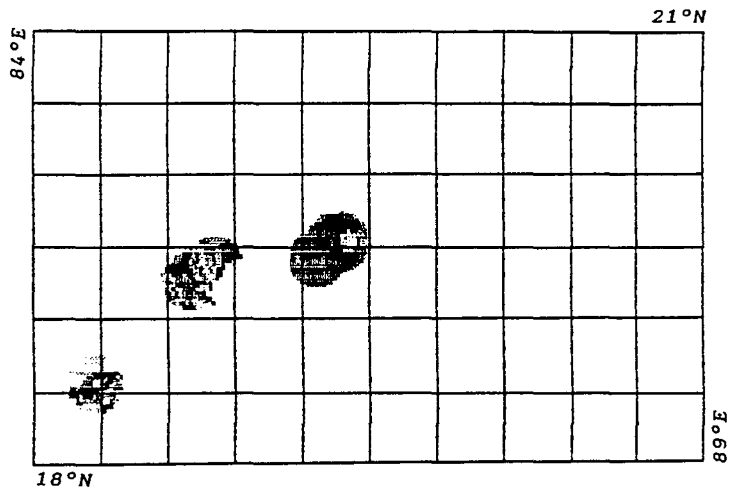


Fig. 4.96 Spatial distribution of Pomfret during December

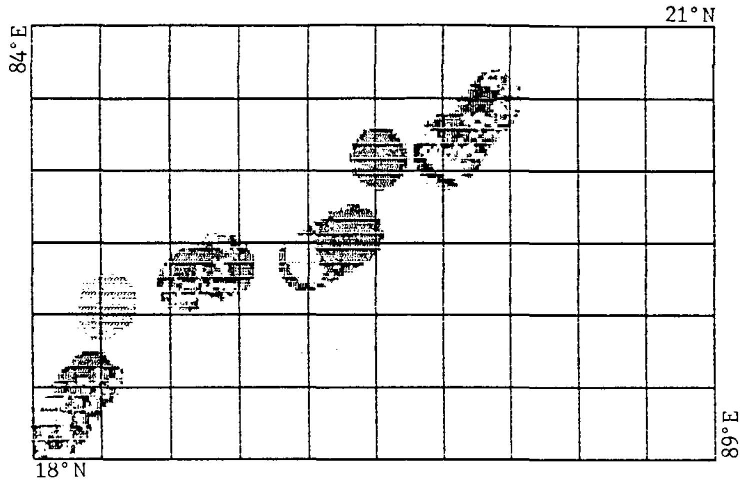


Fig. 4.97

TOTAL ANNUAL DISTRIBUTION OF POMFRET IN NORTH WEST BAY OF BENGAL

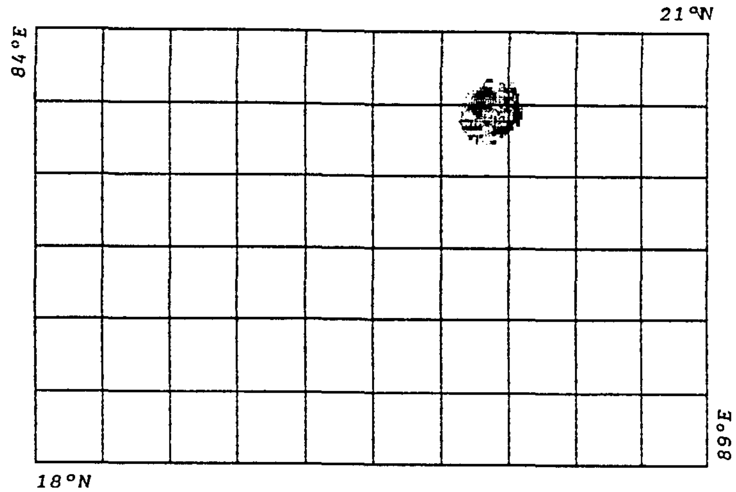


Fig. 4.98 Spatial distribution of Dhoma fish during March

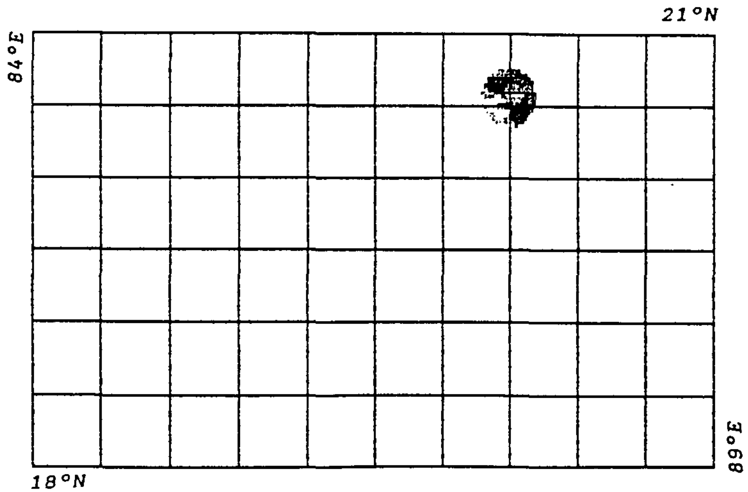


Fig. 4.99 Spatial distribution of Dhoma fish during April

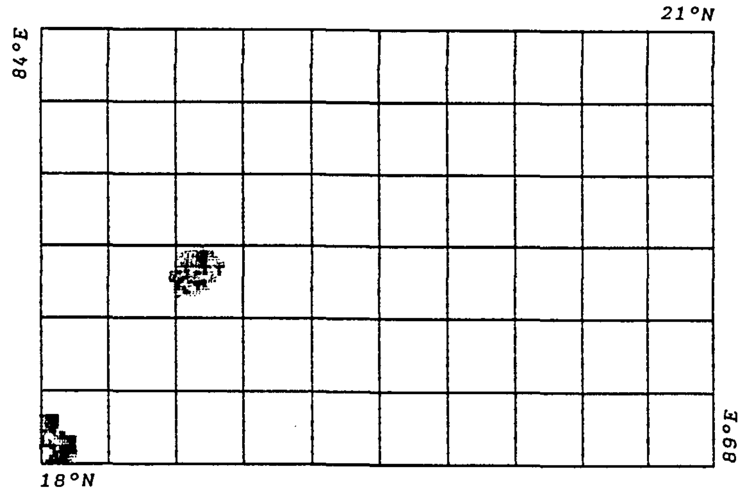


Fig. 4.100 Spatial distribution of Dhoma fish during May

4.2.13 DHOMA

Dhoma were caught in eight out of nine month catches. These were mainly caught in areas between 18°-18°30'N and 84°45'- 85°40'E; 19°10'-19°10'-19°45'N and 85°50'-86°30'E and 19°50'-20°45'N and 86°50'-88°05'E (Fig. 4.98-4.106) in their month-wise and total annual distribution. The catch ranged from 0-263kg with an average catch of 114.6kg/month (Table 4.1) Dhoma were caught in the depth range of 40-80 meters.

4.2.14 LIZARD FISHES

Lizard fishes were caught in eight out of nine month catches. They were mainly caught in areas between 18°-18°30'N and 84°-84°25'E; 19°20'-19°40'N and 86°20'-86°25'E; 19°55'-20°35'N and 86°20'-87°30'E and 20°10'-20°40'N and 87°50'- 88°20'E (Fig. 4.107-4.115) in their month-wise and total annual distribution. The catch ranged from 0-544kg with an average catch of 170.1kg/month (Table 4.1). Lizard fishes were caught in the depth range of 30-70 meters.

4.2.15 NEMIPTERIDS.

Nemipterids were caught in all the nine month catches. They were mainly caught in areas between 18°-18°40'N and 84°-84°35'E; 18°55'-19°30'N and 84°45'-85°35' E; 19°15'-19°45'N and 85°55'-86°30' E; 19°55'-20°40'N and 86°50'-87°40'E and 20°05'-20°40' N and 87°50'-88°20'E (Fig. 4.116-4.124) in their

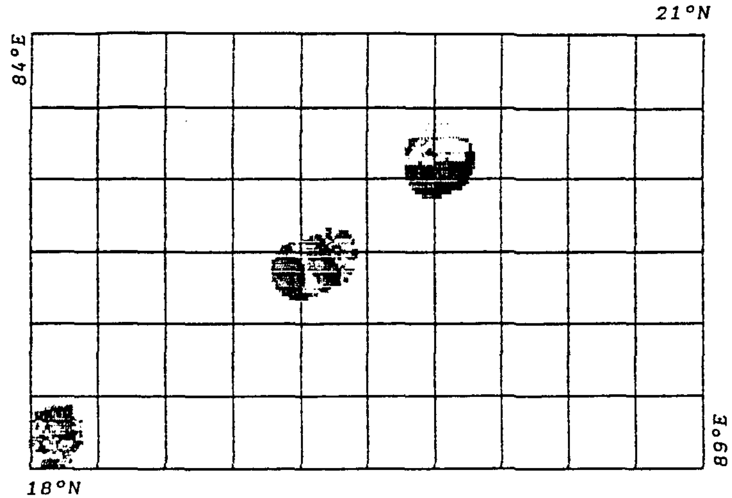


Fig. 4.101 Spatial distribution of Dhoma fish during June

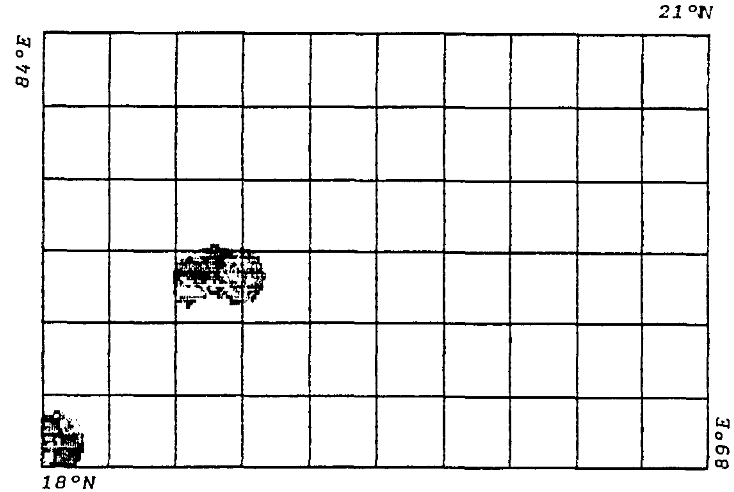


Fig. 4.102 Spatial distribution of Dhoma fish during July

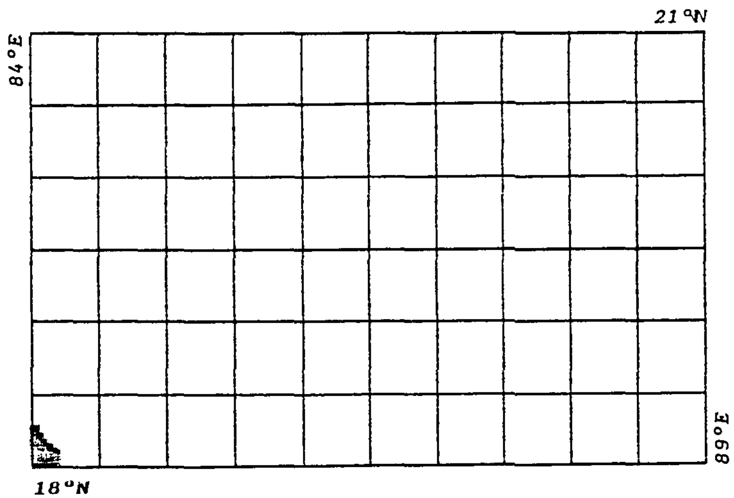


Fig. 4.103 Spatial distribution of Dhoma fish during August

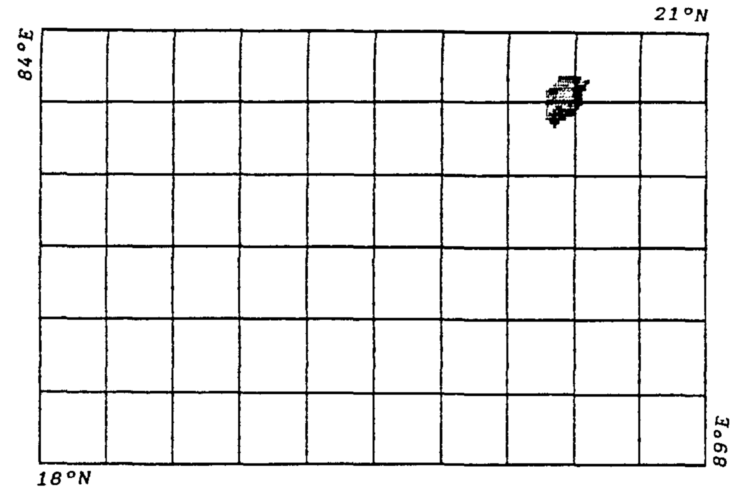


Fig. 4.104 Spatial distribution of Dhoma fish during November

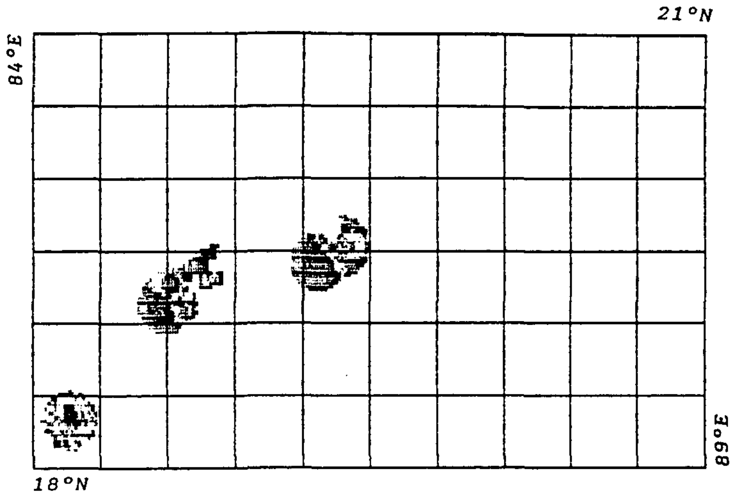


Fig. 4.105 Spatial distribution of Dhoma fish during December

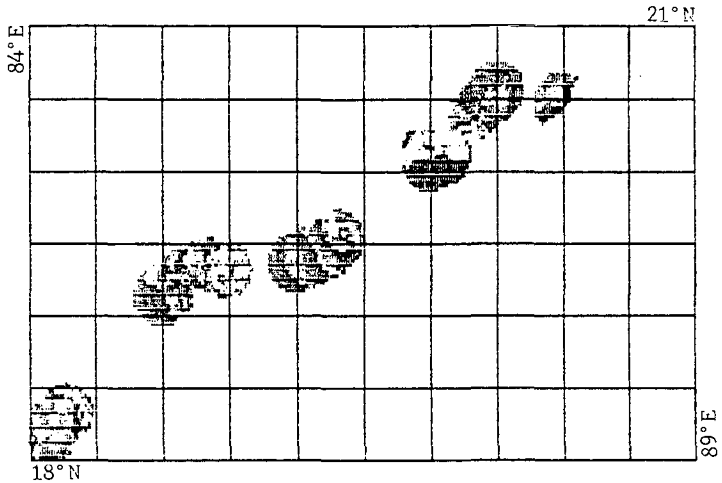


Fig. 4.106

TOTAL ANNUAL DISTRIBUTION OF DHOMA IN NORTH WEST BAY OF BENGAL

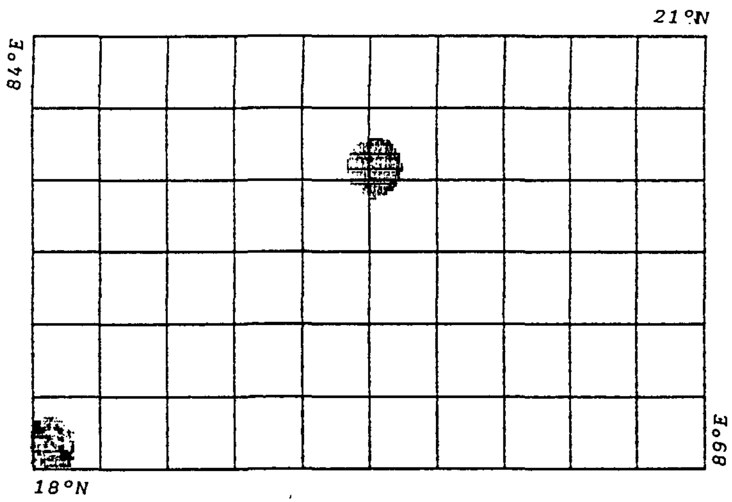


Fig. 4.107 Spatial distribution of Lizard fish during March

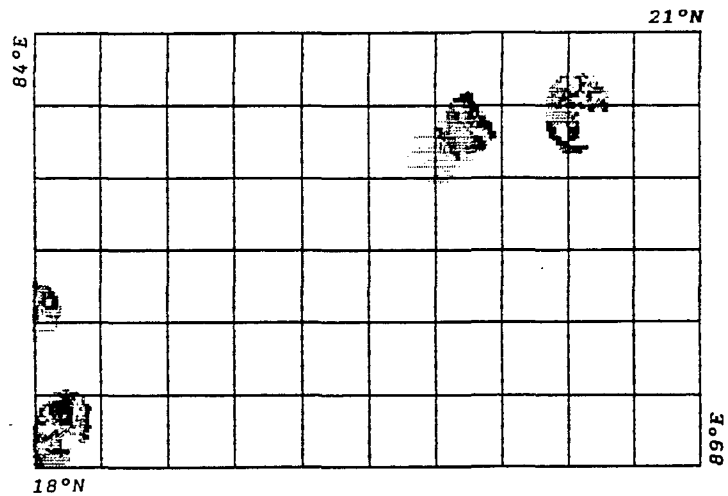


Fig. 4.108 Spatial distribution of Lizard fish during April

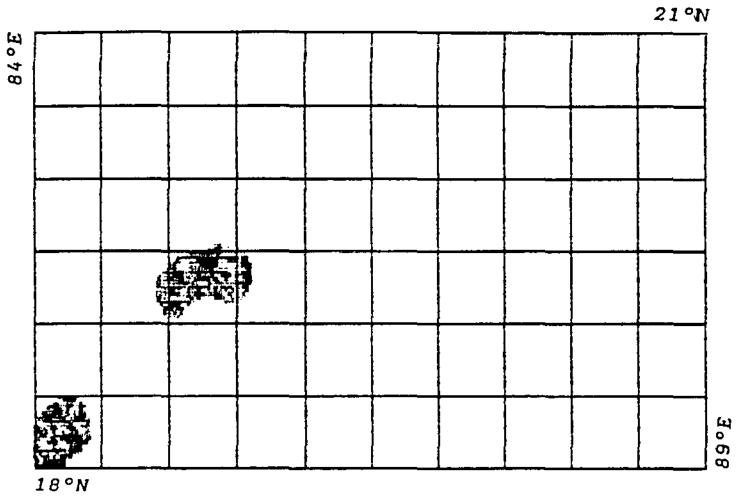


Fig. 4.109 Spatial distribution of Lizard fish during May

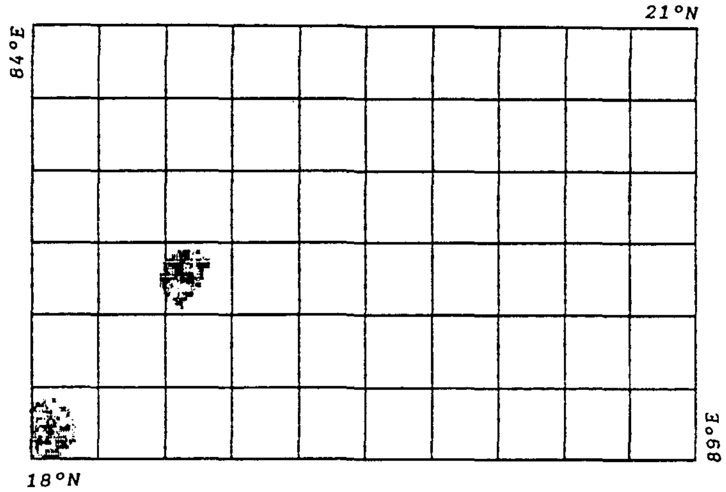


Fig. 4.110 Spatial distribution of Lizard fish during June

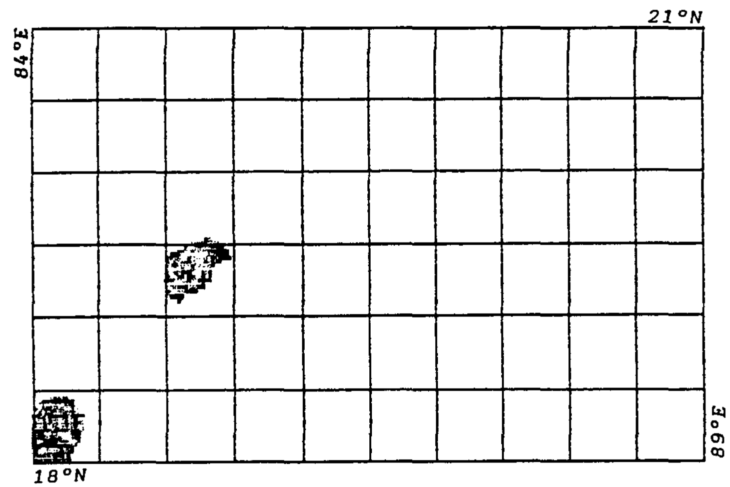


Fig. 4.111 Spatial distribution of Lizard fish during July

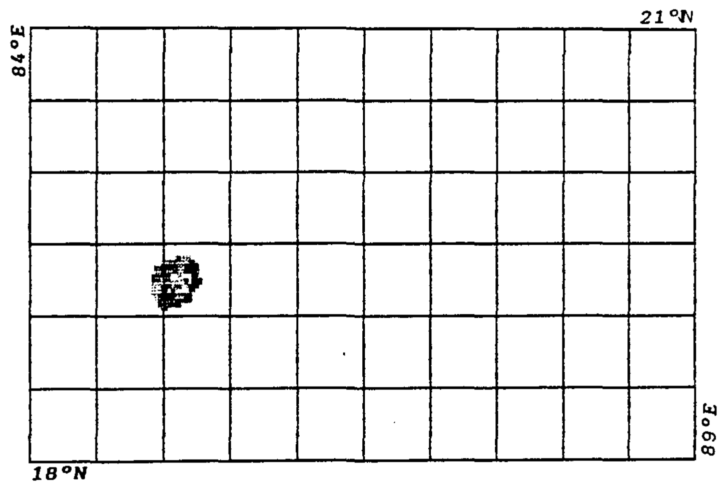


Fig. 4.112 Spatial distribution of Lizard fish during August

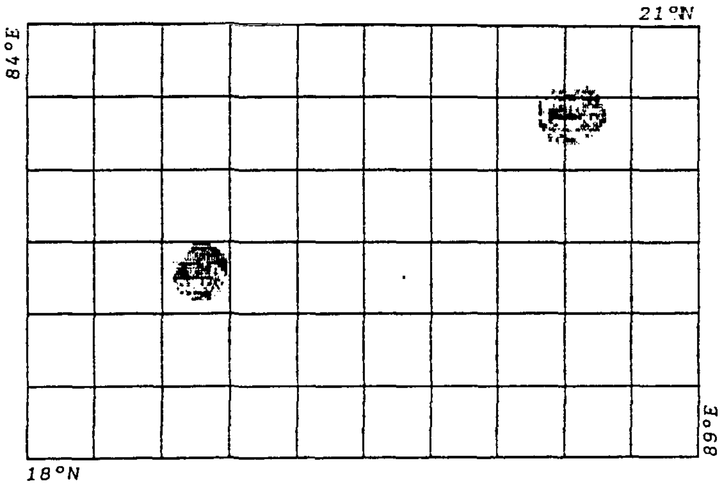


Fig. 4.113 Spatial distribution of Lizard fish during November

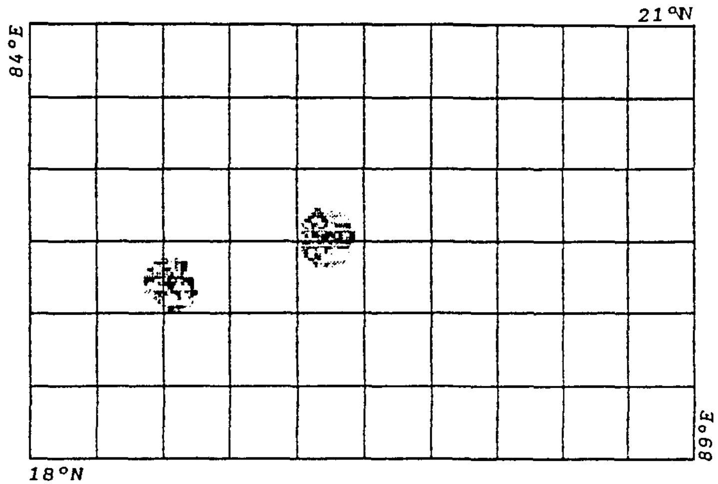


Fig. 4.114 Spatial distribution of Lizard fish during December

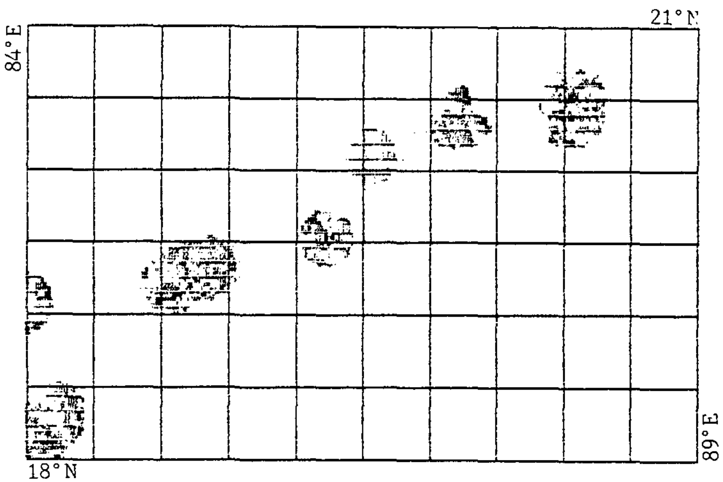


Fig. 4.115

TOTAL ANNUAL DISTRIBUTION OF LIZARD FISH IN NORTH WEST BAY OF BENGAL

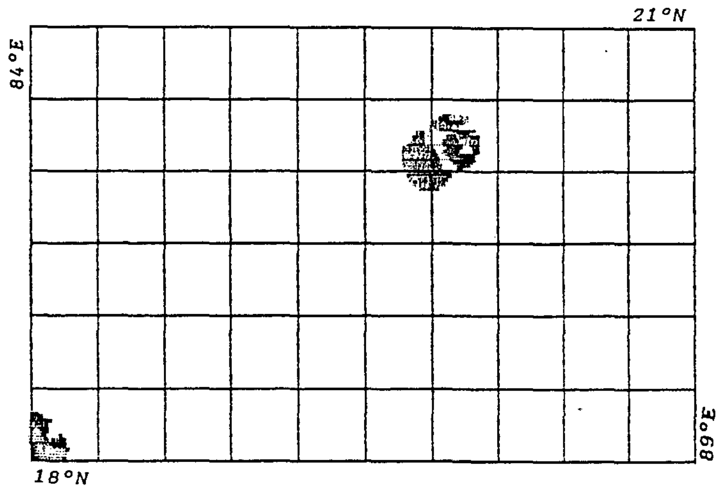


Fig. 4.116 Spatial distribution of Nemipterids during February

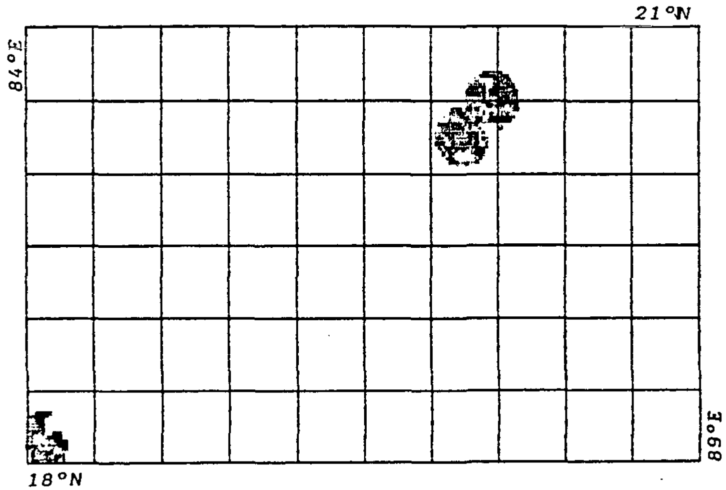


Fig. 4.117 Spatial distribution of Nemipterids during March

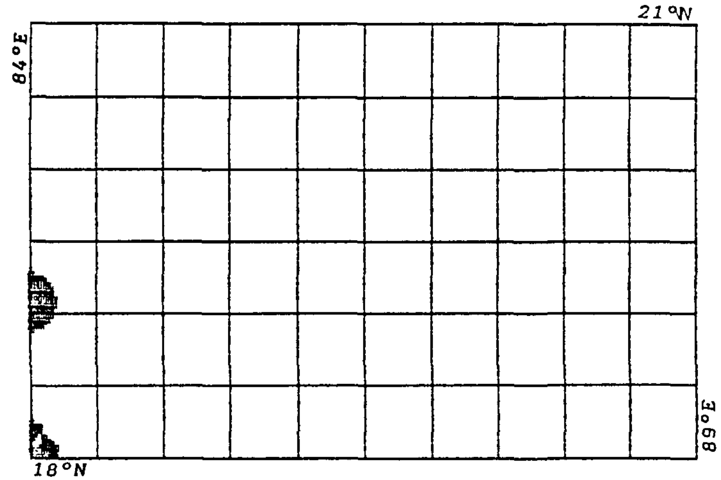


Fig. 4.118 Spatial distribution of Nemipterids during April

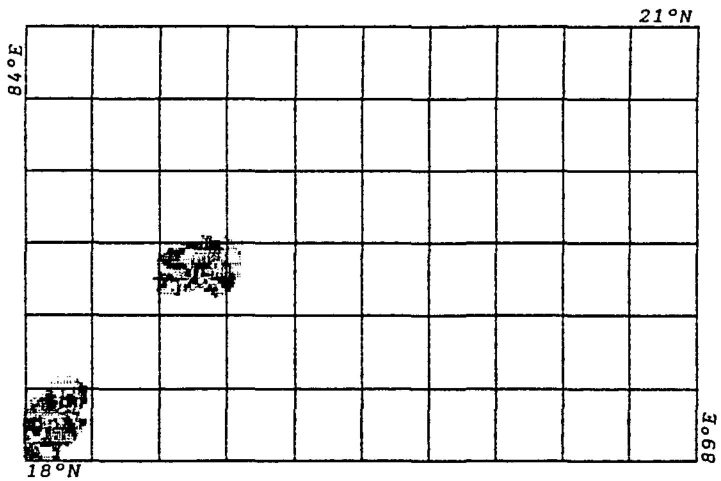


Fig. 4.119 Spatial distribution of Nemipterids during May

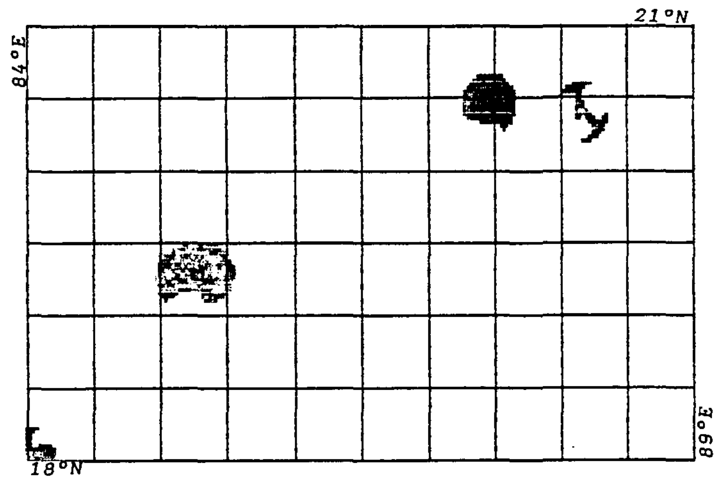


Fig. 4.120 Spatial distribution of Nemipterids during July

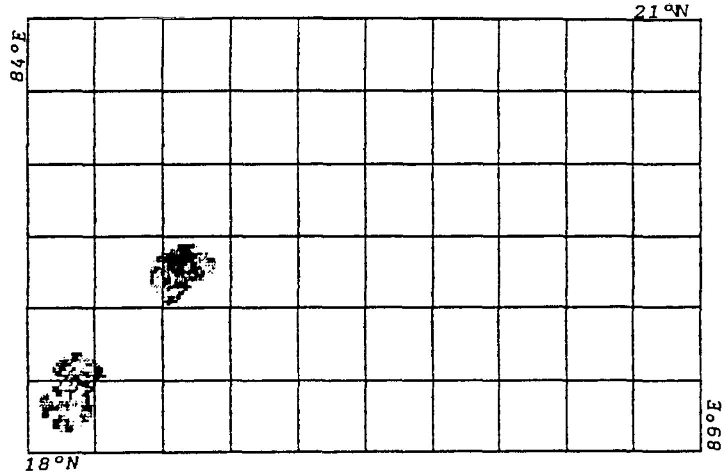


Fig. 4.121 Spatial distribution of Nemipterids during August

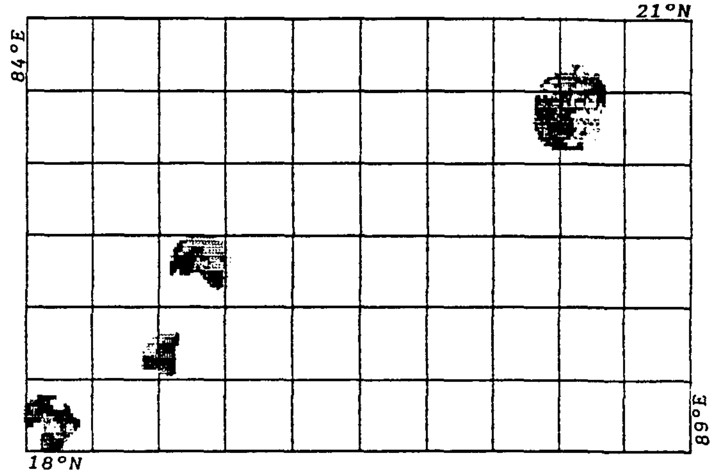


Fig. 4.122 Spatial distribution of Nemipterids during November

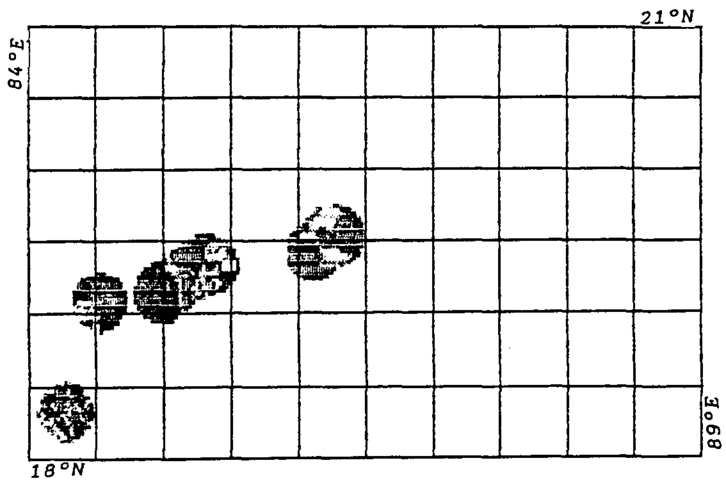


Fig. 4.123 Spatial distribution of Nemipterids during December

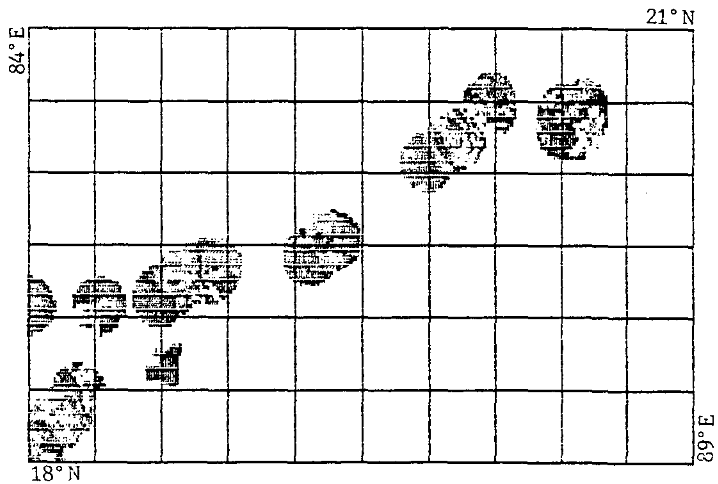


Fig. 4.124

TOTAL ANNUAL DISTRIBUTION OF NEMIPTERIDS IN NORTH WEST BAY OF BENGA month-wise and total annual distribution. The catch ranged from 39-2929kg with an average catch of 892kg/month (Table 4.1). Nemipterids were caught in the depth range of 40-170 meters.

4.2.16 LEOGNATHIDS

Leognathids were caught in six out of nine month catches. They were mainly caught in areas between 18°-18°45'N and 84°-84°40'E; 19°- 19° 30'N and 84°50'-85°35'E; 19°15'-19°45'N and 85°50'-86°30'E and 20°-20°40'N and 86°55'-87°40' E (Fig. 4.125-4.131) in their month-wise and total annual distribution. The catch ranged from 0-1759kg with an average catch of 560kg/month (Table 4.1). Leognathids were caught in the depth range of 40-70 meters.

4.2.17 UPENOIDS

Upenoids were caught in all the nine month catches. They were mainly caught in areas between 18°-18°45'N and 84°-84°40'E; 18°50'-19°35'N and 84°50'-85°35'E; 19°10'-19°45'N and 85°50'-87°40'E and 20°10'-20°40' N and 87°50'-88°15' E (Fig. 4.132-4.41) in their month-wise and total annual distribution. The catch ranged from 113-1693kg with an average catch of 637.4kg/month (Table 4.1). Upenoids were caught in the depth range of 30-110 meters.

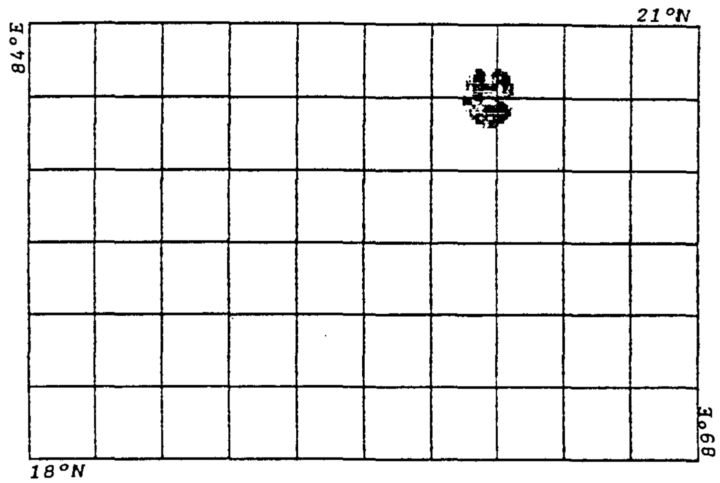


Fig. 4.125 Spatial distribution of Leognathids during April

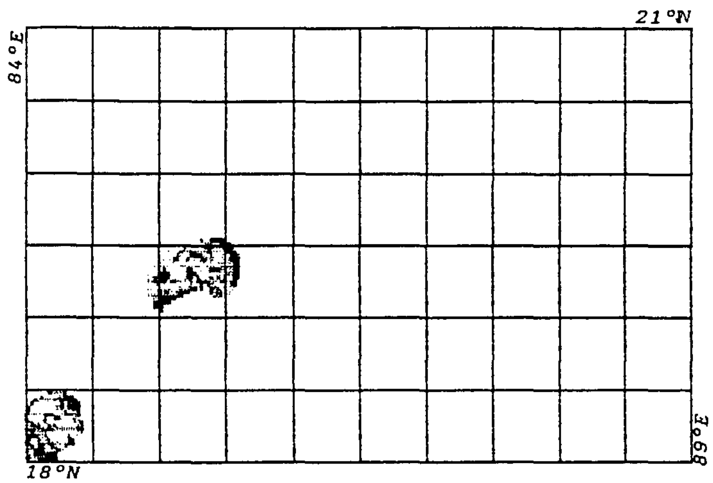


Fig. 4.126 Spatial distribution of Leognathids during May

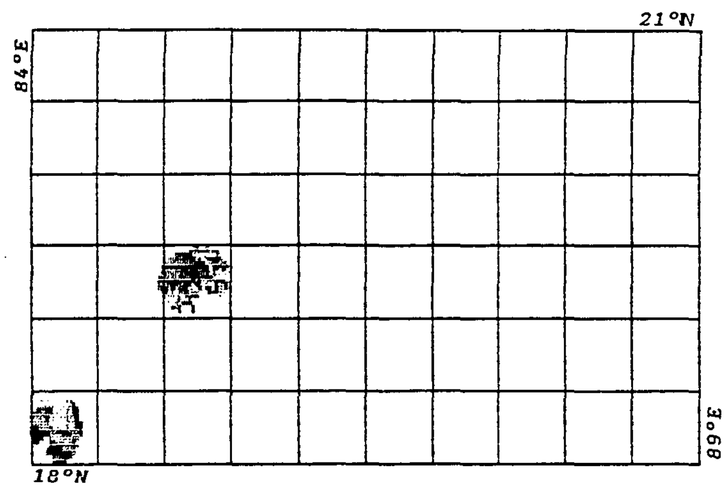


Fig. 4.127 Spatial distribution of Leognathids during June

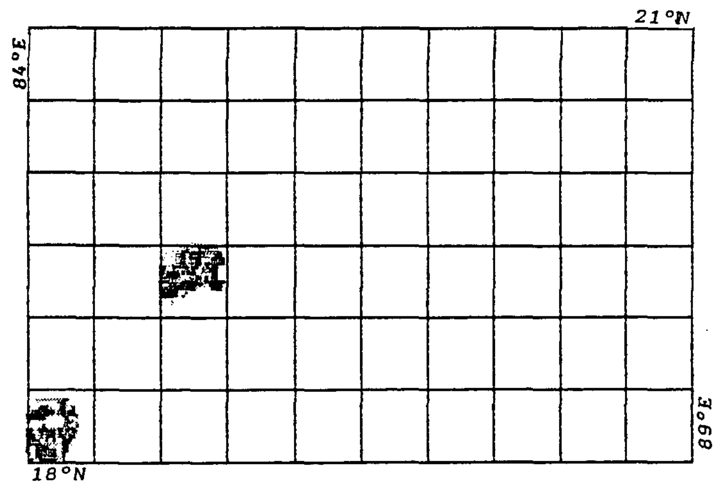


Fig. 4.128 Spatial distribution of Leognathids during July

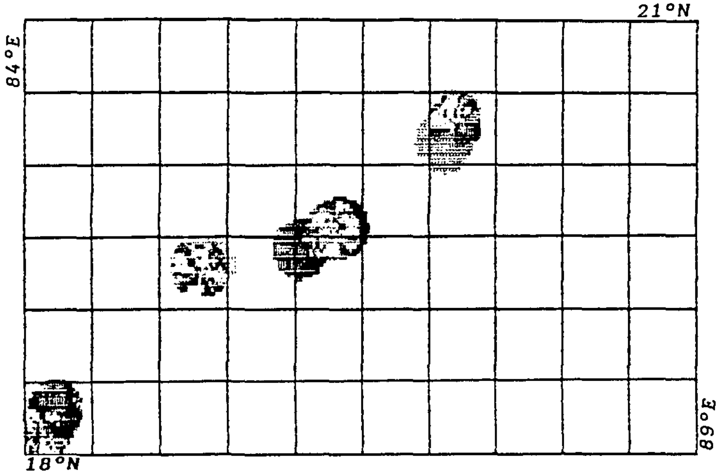


Fig. 4.129 Spatial distribution of Leognathids during November

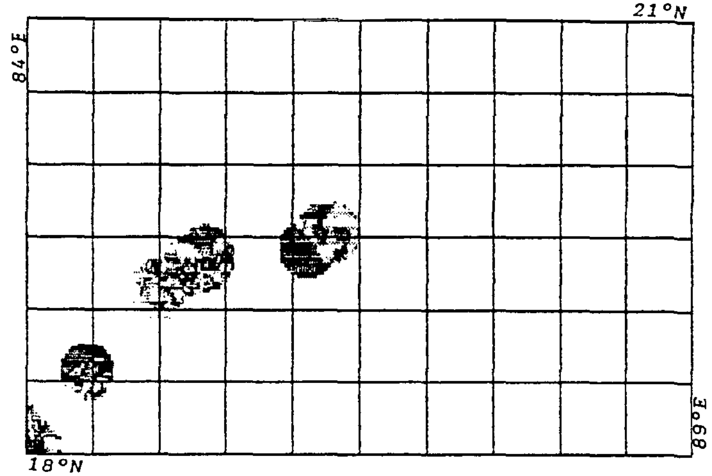


Fig. 4.130 Spatial distribution of Leognathids during December

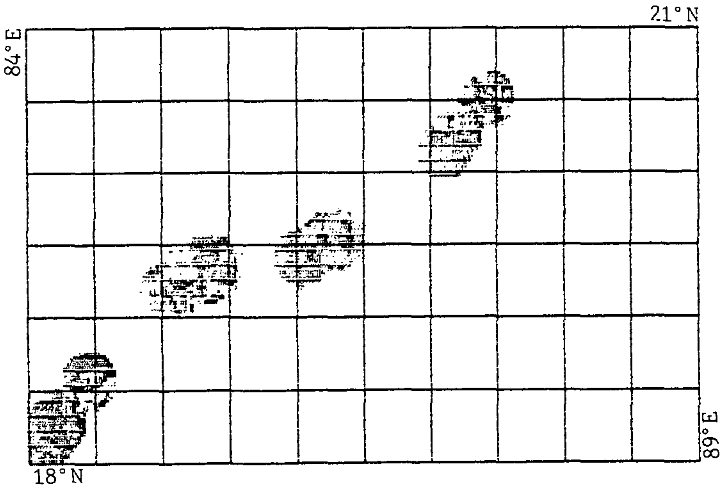


Fig.4.131

TOTAL ANNUAL DISTRIBUTION OF LEOGNATHIDS IN NORTH WEST BAY OF BENGAL

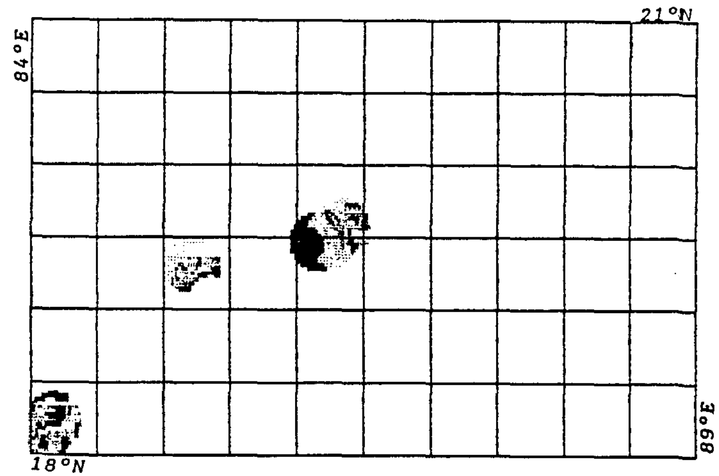


Fig. 4.132 Spatial distribution of Upenoids during February

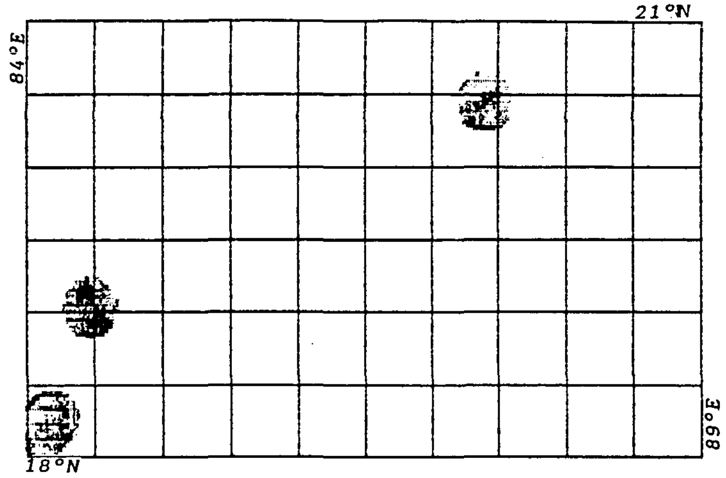


Fig. 4.133 Spatial distribution of Upenoids during March

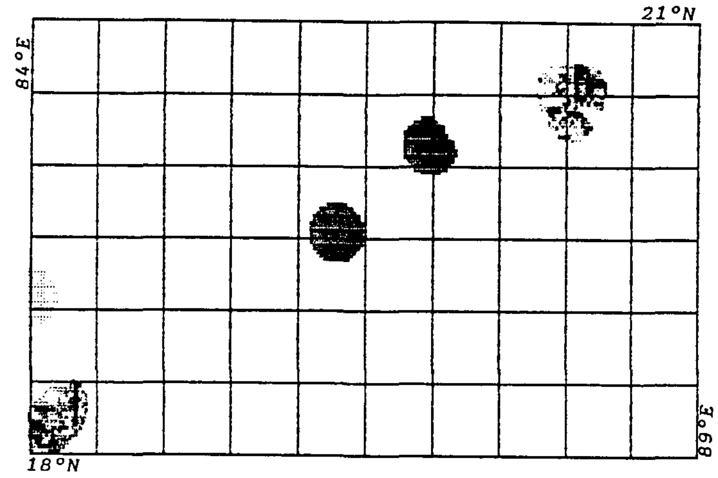


Fig. 4.134 Spatial distribution of Upenoids during April

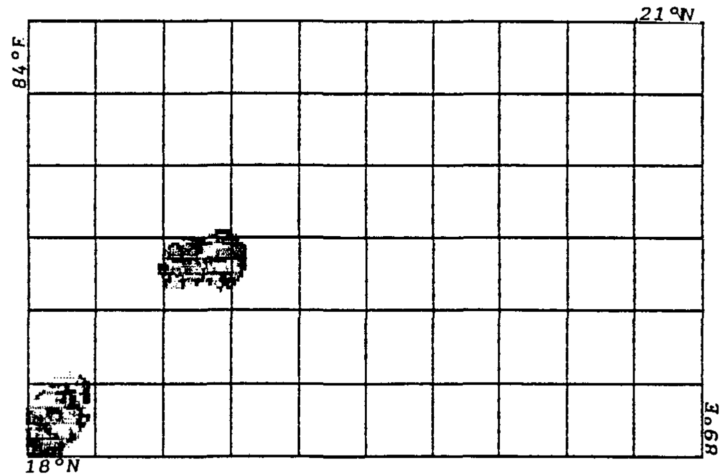


Fig. 4.135 Spatial distribution of Upenoids during May

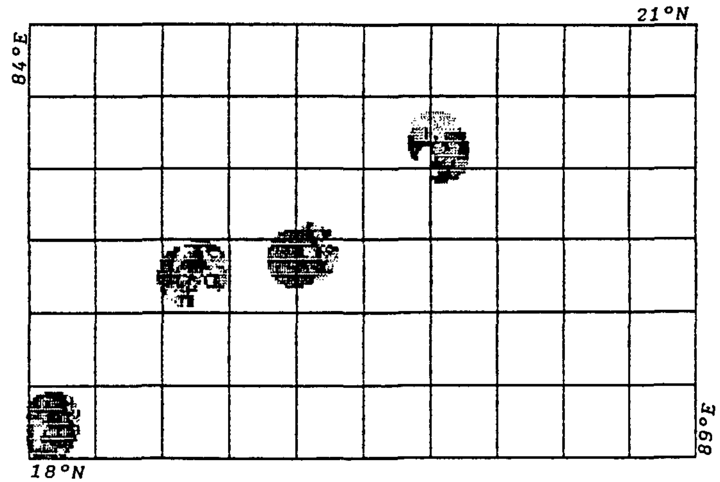


Fig. 4.136 Spatial distribution of Upenoids during June

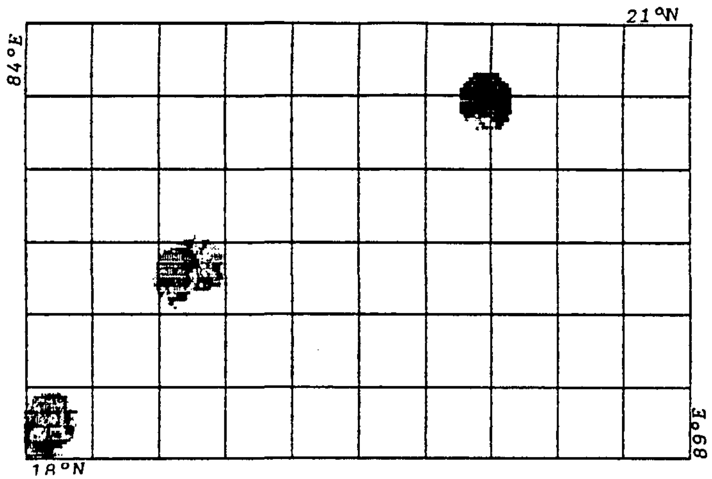


Fig. 4.137 Spatial distribution of Upenoids during July

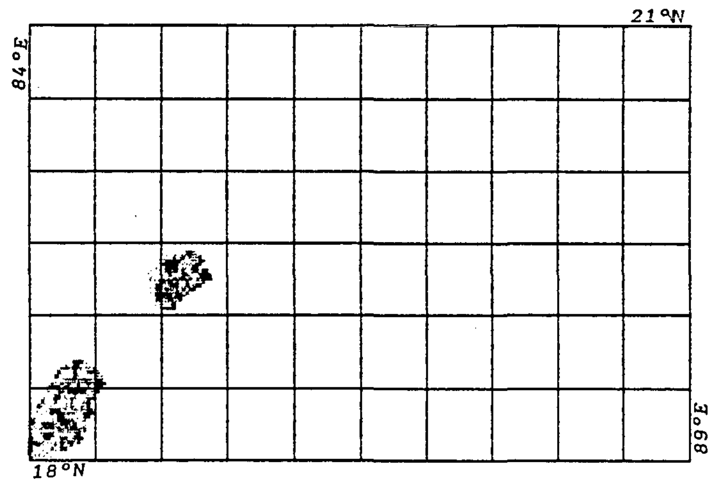


Fig. 4.138 Spatial distribution of Upenoids during August

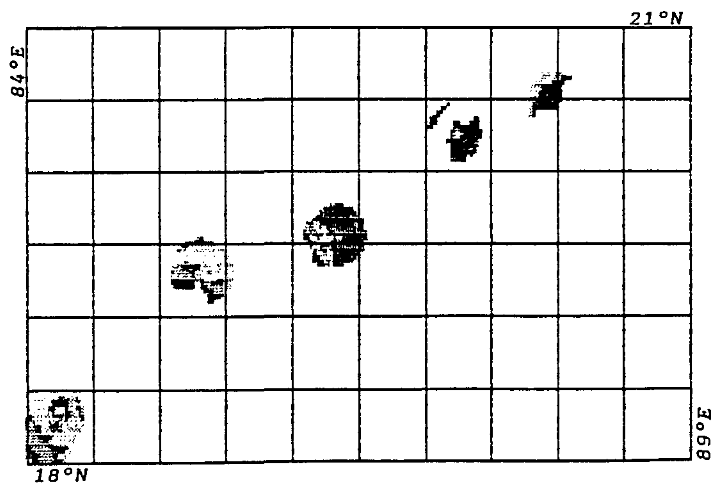


Fig. 4.139 Spatial distribution of Upenoids during November

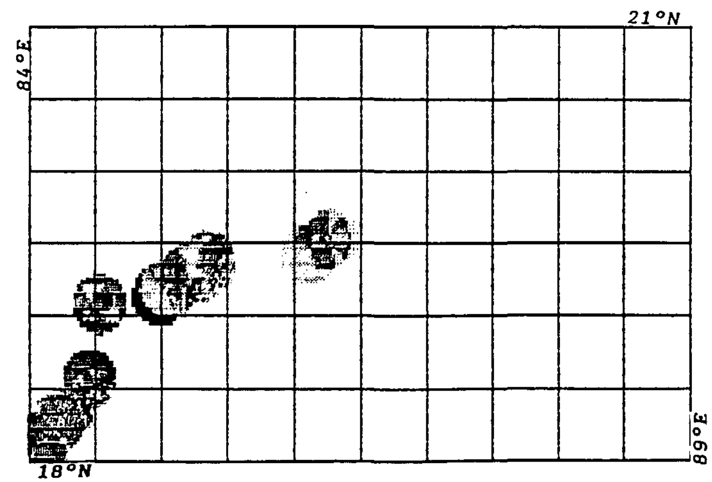


Fig. 4.140 Spatial distribution of Upenoids during December

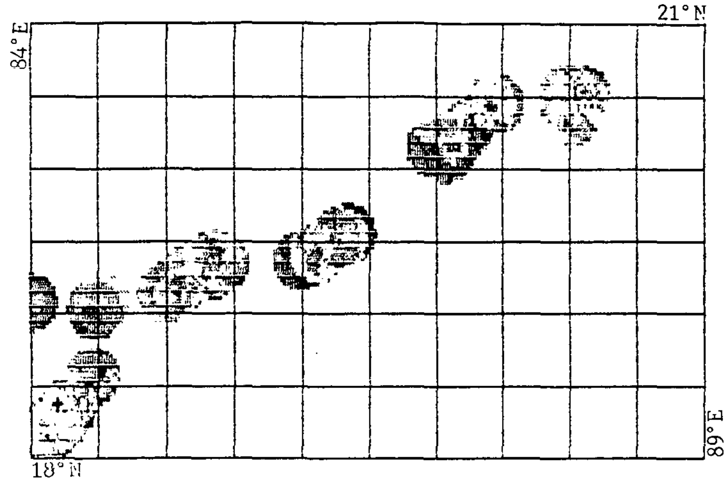


Fig. 4.141

TOTAL ANNUAL DISTRIBUTION OF UPENOIDS IN NORTH WEST BAY OF BENGAL

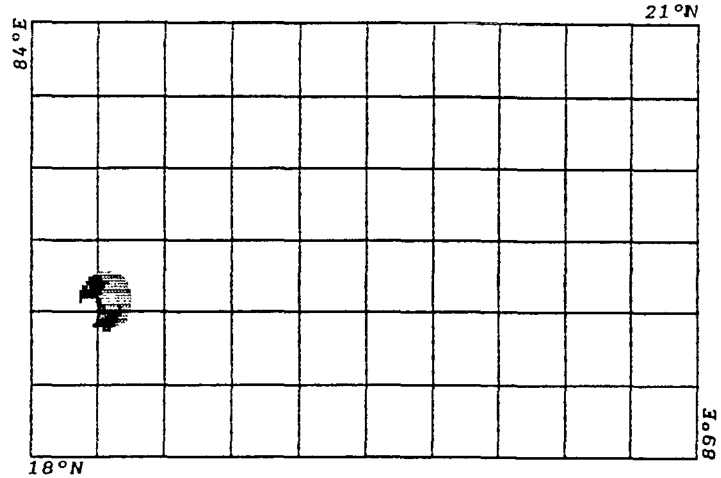


Fig. 4.142 Spatial distribution of Flatfish during March

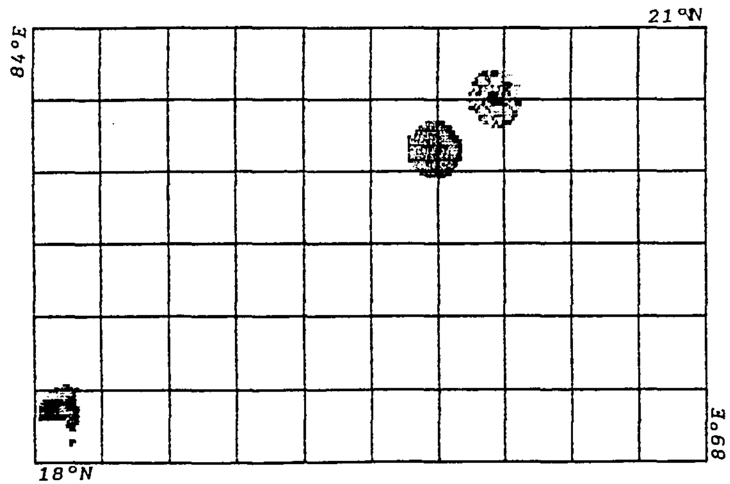


Fig. 4.143 Spatial distribution of Flat fish during April

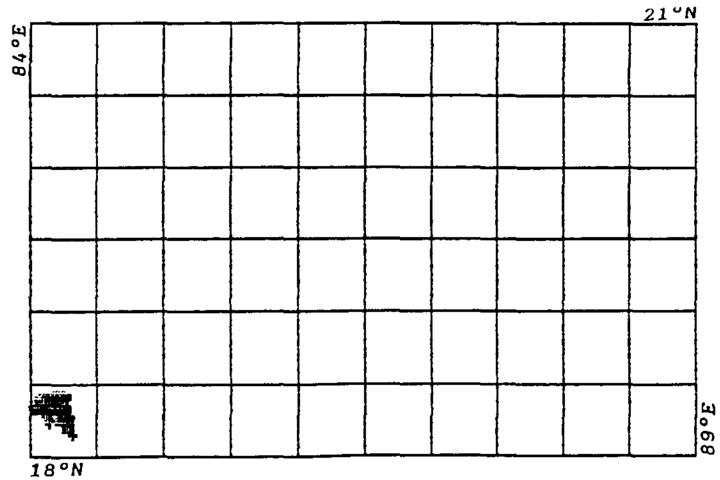


Fig. 4.144 Spatial distribution of Flat fish during June

4.2.18 FLATFISHES

Flatfishes were caught in five out of nine month catches. They were mainly caught in areas between 18°10'-18°30'N and 84°-84°20'E; 18°50'-19°15'N and 84°20-84°45'E; 19°20'- 19°35'N and 85°10'-85°35'E; 20°-20°20'N and 86°45'-87°10'E and 20°20'-20°45'N and 87°15'-87°40'E (Fig. 4.142-4.147) in their month-wise and total annual distribution. The catch ranged from 0-29kg with an average catch of 5.4kg/month (Table 4.1). Flatfishes were caught in the depth range of 30-60 meters.

4.2.19 PRAWNS

Prawns were caught in five out of the nine month catches. They were mainly caught in the areas between 18°-18°25'N and 84°-84°20'E; 18°50'-19°30'N and 85°-85°30'E; 19°10'-19°35'N and 85°50-86°10'E and 19°55'-20°15'N and 86°50'-87°40'E (Fig. 4.148-4.153) in their month-wise and total annual distribution. The catch ranged from 0-9kg with an average catch of 3.2kg/month (Table 4.1). Prawns were caught in the depth range of 40-215 meters.

4.2.20 CUTTLE FISHES

Cuttle fishes were caught in six out of nine month catches. They were mainly caught in areas between 18°-18°45'N and 84°-84°40'E; 19°-19°30'N and 84°50'-85°30'E; 19°15'-19°40'N and

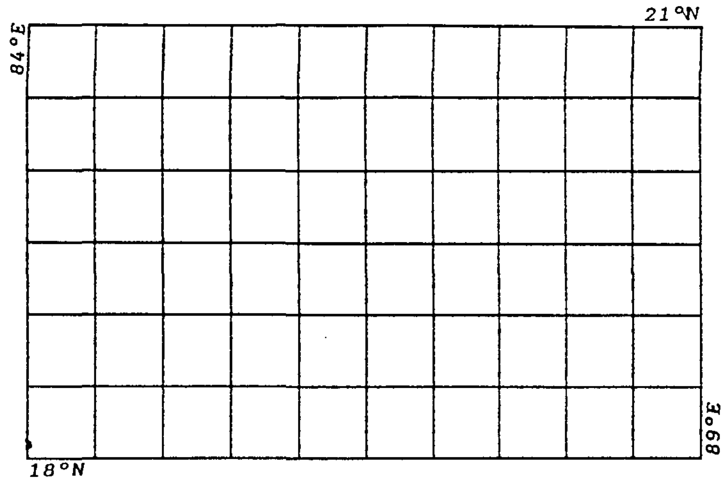


Fig. 4.145 Spatial distribution of Flat fish during July

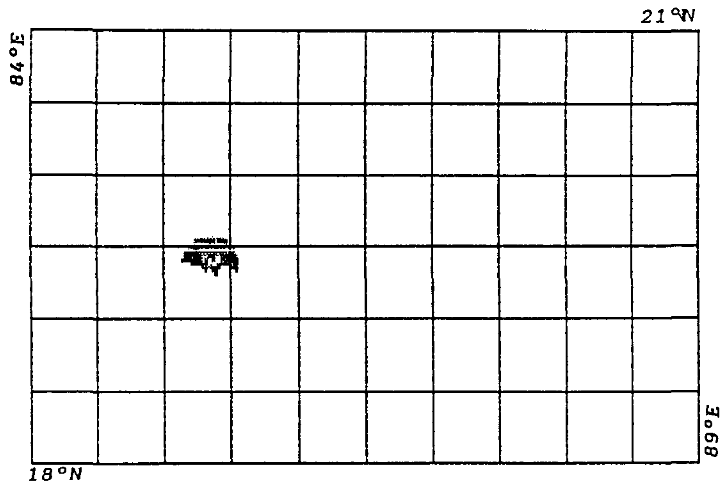


Fig. 4.146 Spatial distribution of Flat fish during December

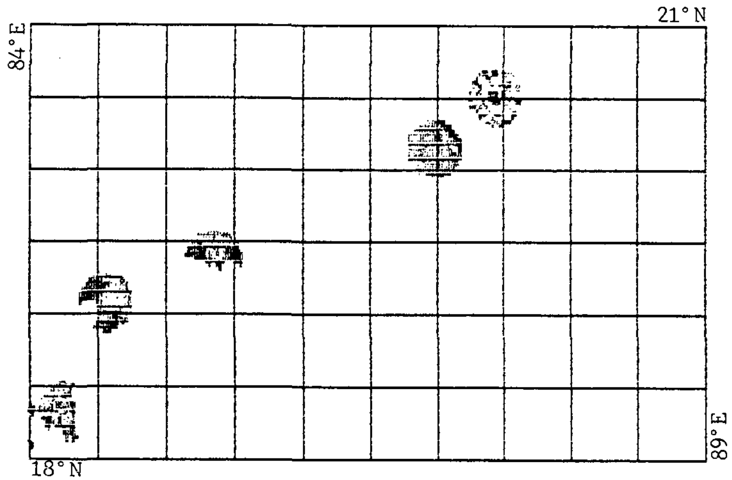


Fig. 4.147

TOTAL ANNUAL DISTRIBUTION OF FLAT FISH IN NORTH WEST BAY OF BENGAL

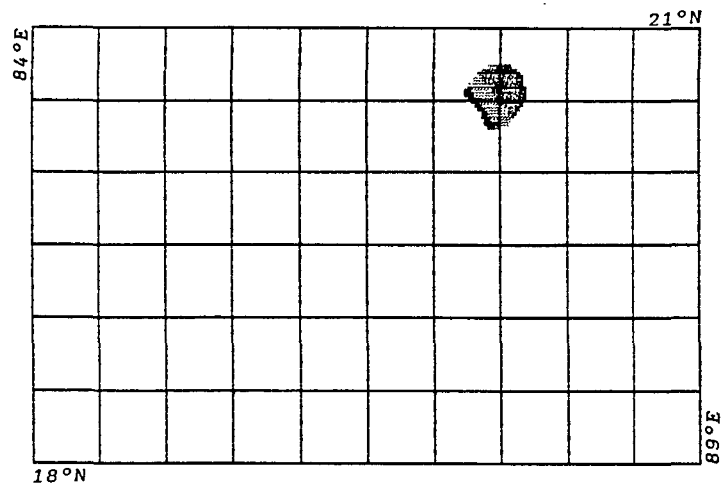


Fig. 4.148 Spatial distribution of Prawn during April

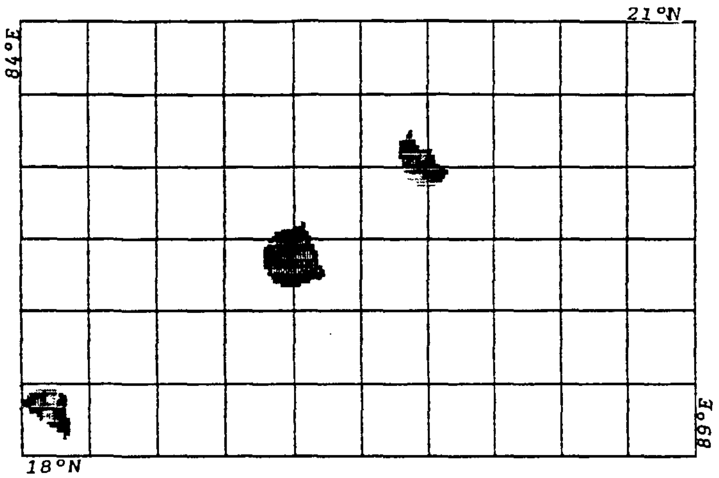


Fig. 4.149 Spatial distribution of Prawn during June

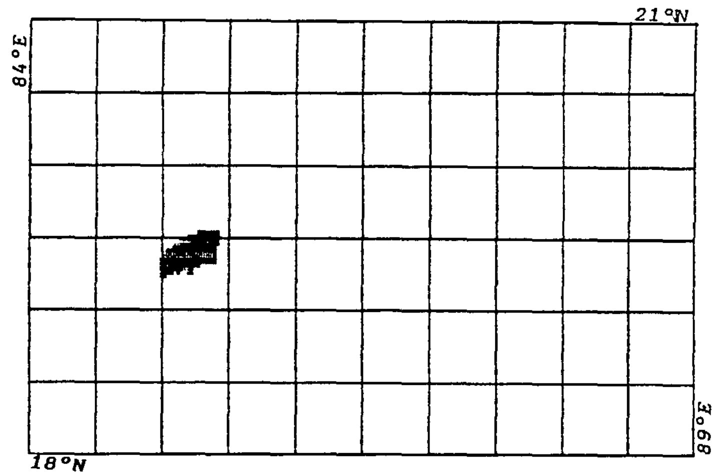


Fig. 4.150 Spatial distribution of Prawn during July

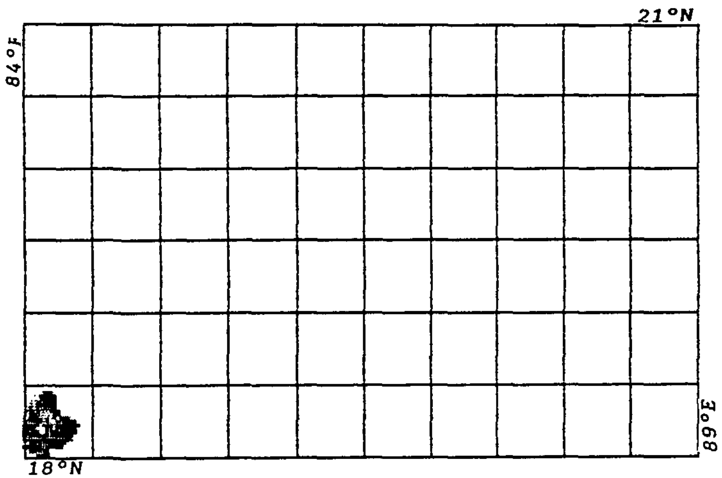


Fig. 4.151 Spatial distribution of Prawn during August

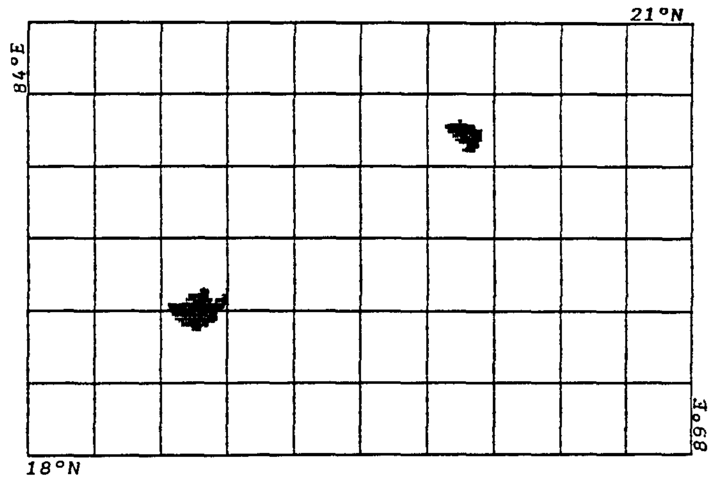


Fig. 4.152 Spatial distribution of Prawn during November

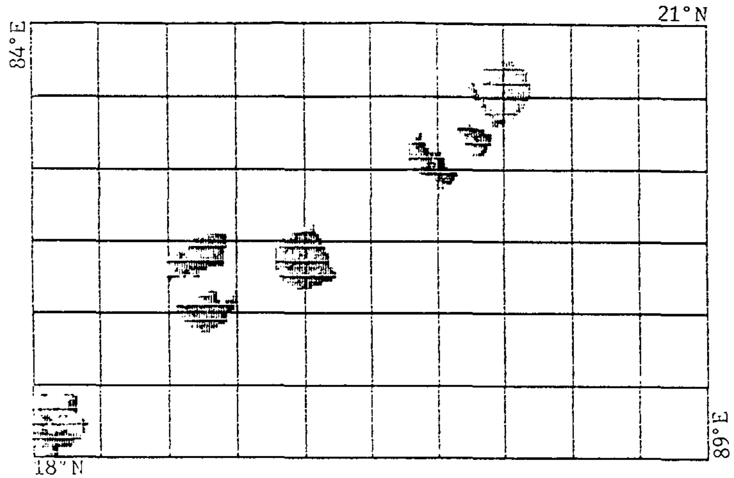


Fig. 4.153

TOTAL ANNUAL DISTRIBUTION OF PRAWN IN NORTH WEST BAY OF BENGAL

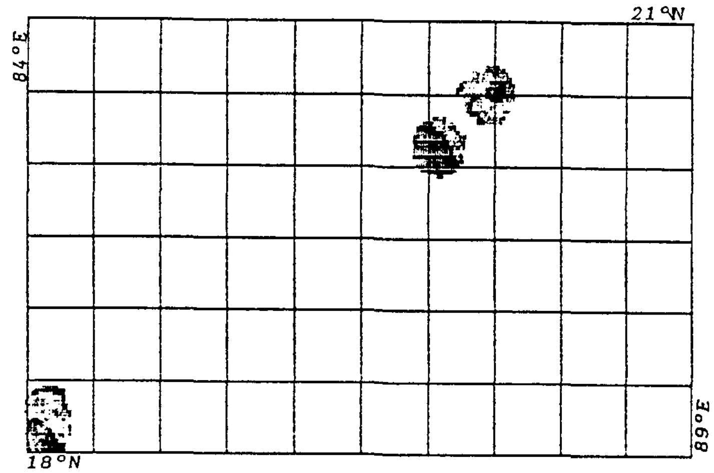


Fig. 4.154 Spatial distribution of Cuttle fish during March

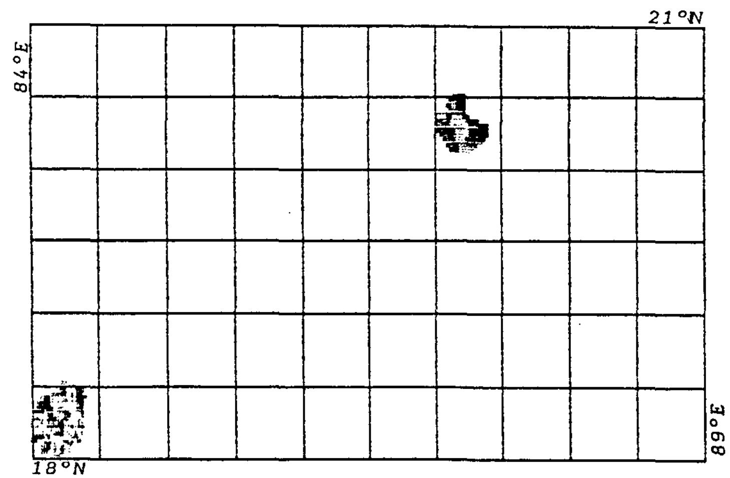


Fig. 4.155 Spatial distribution of Cuttle fish during April

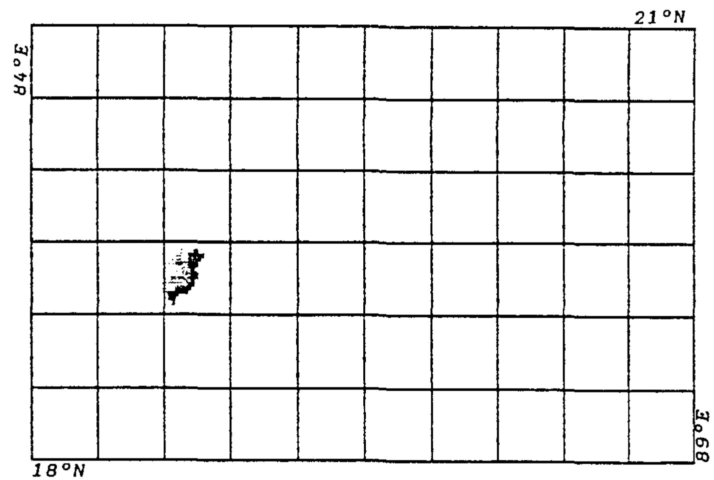


Fig. 4.156 Spatial distribution of Cuttle fish during June

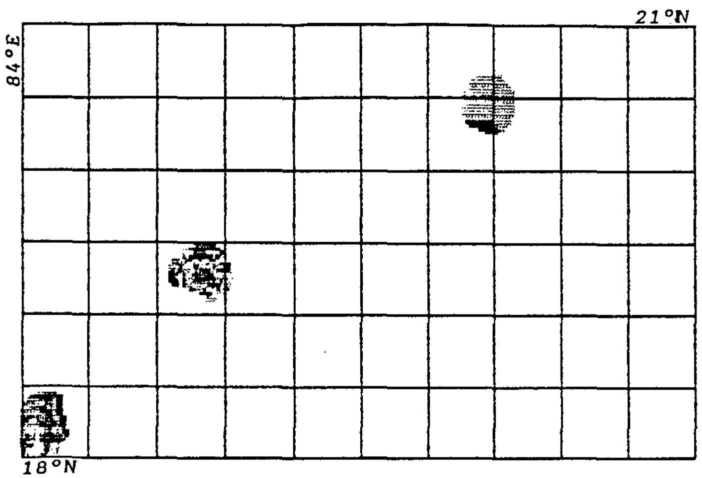


Fig. 4.157 Spatial distribution of Cuttle fish during July

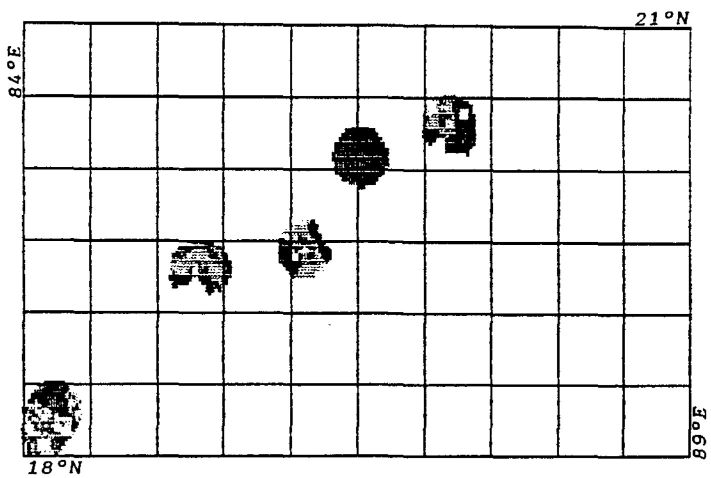


Fig. 4.158 Spatial distribution of Cuttle fish during November

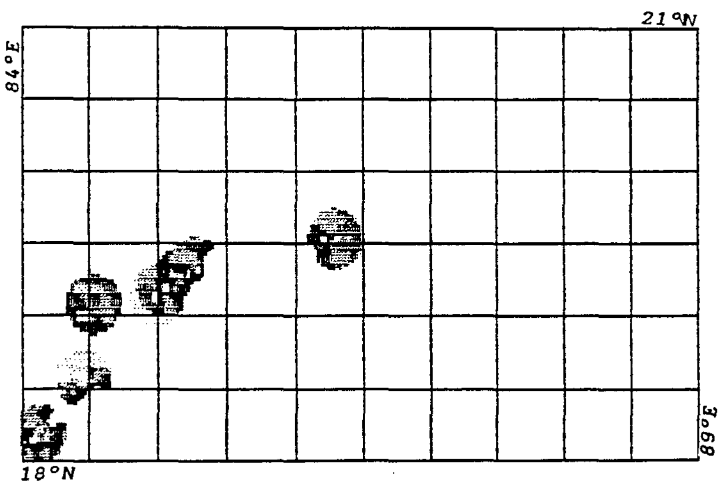


Fig. 4.159 Spatial distribution of Cuttle fish during December

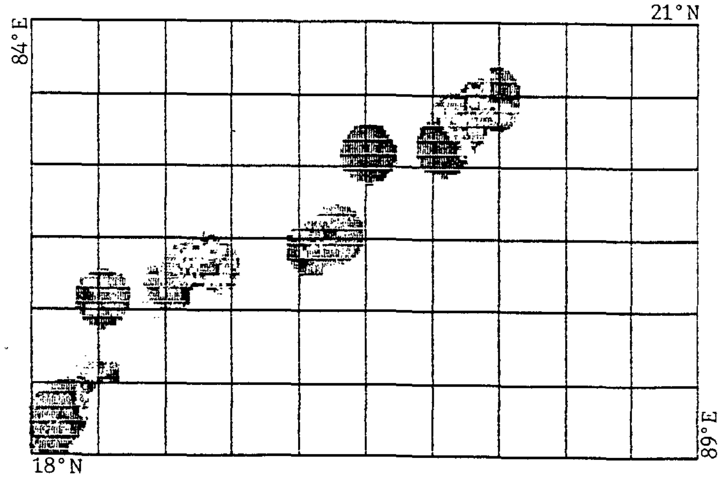


Fig. 4.160

TOTAL ANNUAL DISTRIBUTION OF CUTTLE FISH IN NORTH WEST BAY OF BENGAL

85°55'-86°30'E; 19°55'-20°15'N and 86°50'-87°15'E and 20°-20°45'N and 86°55'-87°40'E (Fig. 4.154-4.160) in their month-wise and total annual distribution. The catch ranged from 0-11kg with an average catch of 43.7kg/month (Table 4.1). Cuttle fishes were caught in the depth range of 30-75 meters.

4.2.21 CLUPEIDS

Clupeids were caught in five out of the nine month catches. They were mainly caught in areas between 18°20'-18°30'N and 84°-84°20'E; 19°-19°30'N and 84°50'-85°35'E; 19°10'-19°45'N and 85°50' - 86°30'E and 20°-20°45'N and 86°50'-88°05'E (Fig. 4.161-4.166) in their month-wise and annual distribution. The catch ranged from 0-739kg with an average catch of 133.1kg/month (Table 4.1). Clupeids were caught in the depth range of 30-70 meters.

4.2.22 CARANGIDS

Carangids were caught in all the nine month catches. They were mainly caught in areas between 18°-18°45'N and 84°-84°40'E; 19°-19°35'N and 84°55'-85°30' E; Lat. 19°10' - 19°45'N and 84°55'-85°30'E; 19°10-19°45'N and 85° 50'-86°35' E and 20°-20°10'N and 86°50'-88°15'E (Fig. 4.167-4.176) in their month-wise and total annual distribution. The catch ranged from 31-406kg with an average catch of 232.1kg/month (Table 4.1). Carangids were caught in the depth range of 30-70 meters.

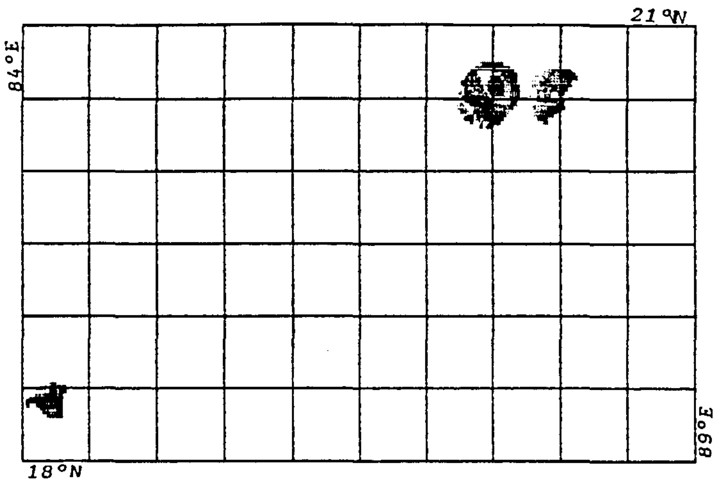


Fig. 4.161 Spatial distribution of Clupeids during April

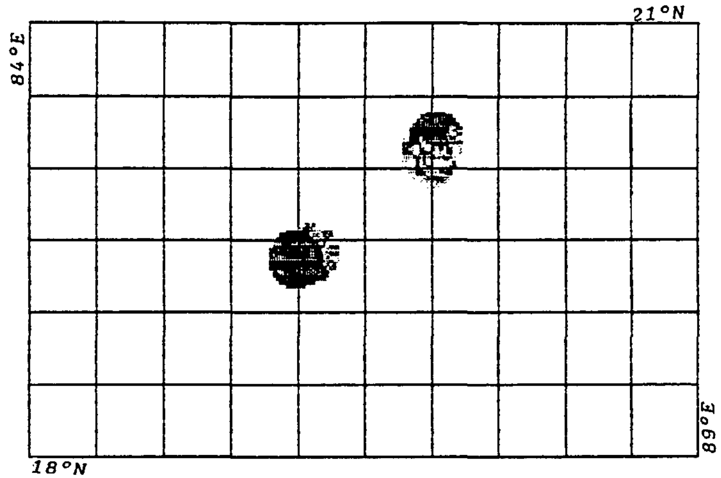


Fig. 4.162 Spatial distribution of Clupeids during June

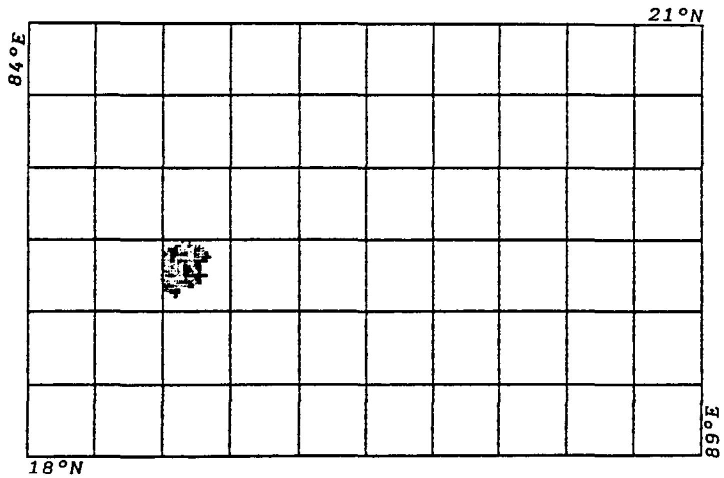


Fig. 4.163 Spatial distribution of Clupeids during July

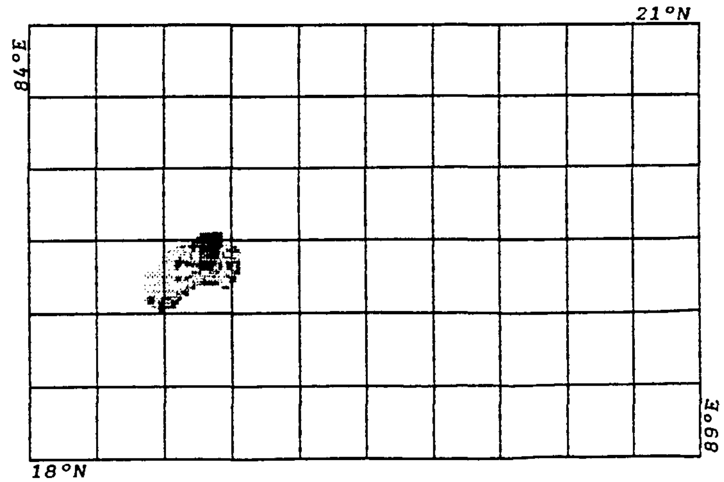


Fig. 4.164 Spatial distribution of Clupeids during August

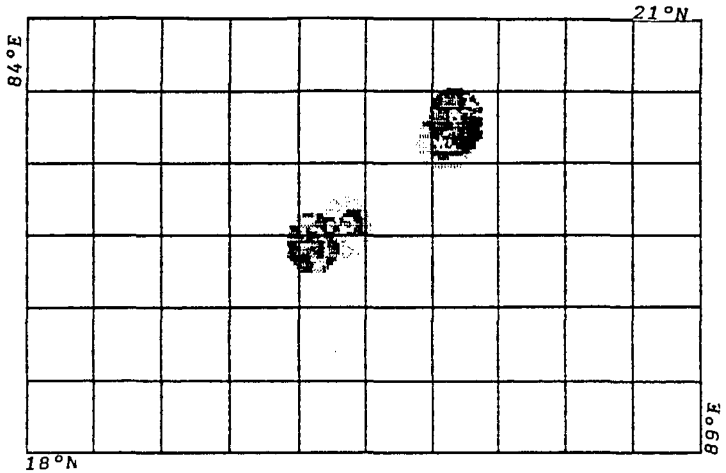


Fig. 4.165 Spatial distribution of Clupeids during November

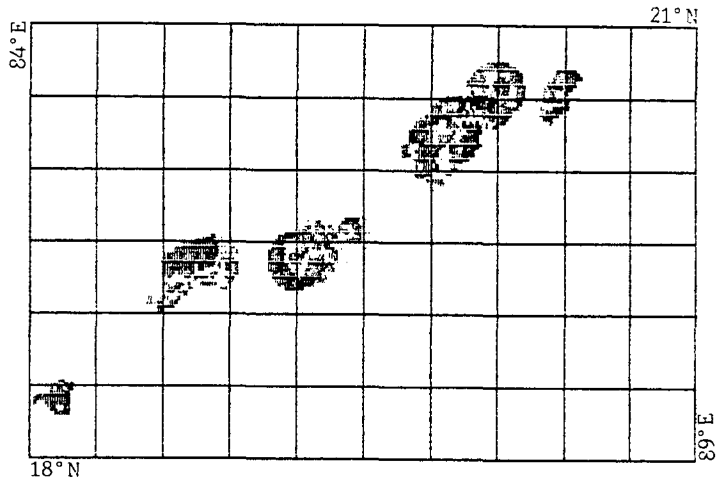


Fig. 4.166

TOTAL ANNUAL DISTRIBUTION OF CLUPEIDS IN NORTH WEST BAY OF BENGAL

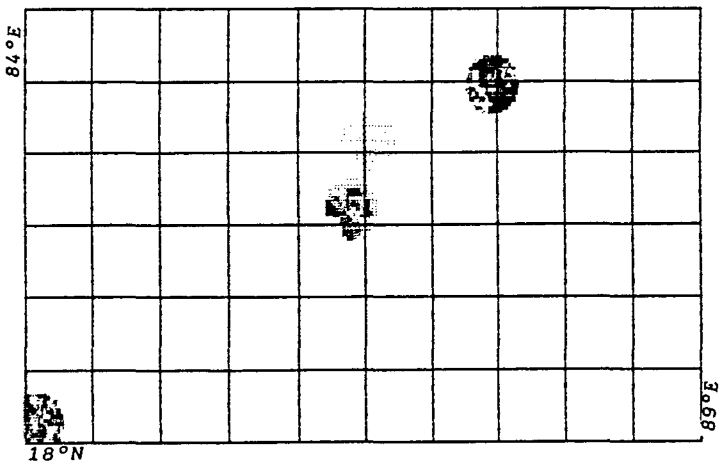


Fig. 4.167 Spatial distribution of Caranx during February

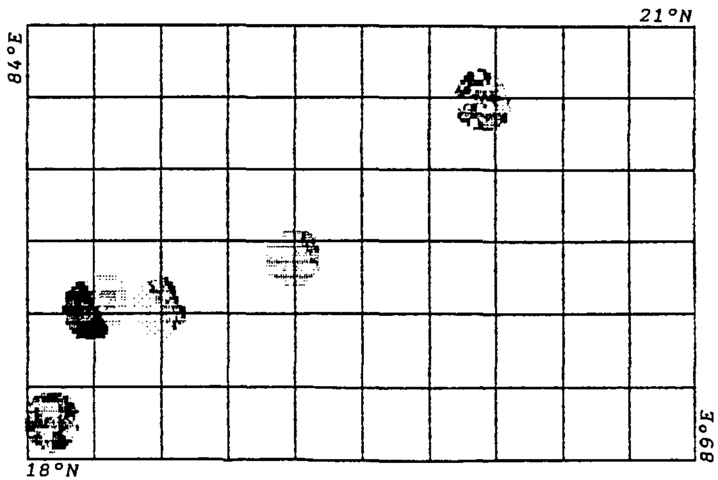


Fig. 4.168 Spatial distribution of Caranx during March

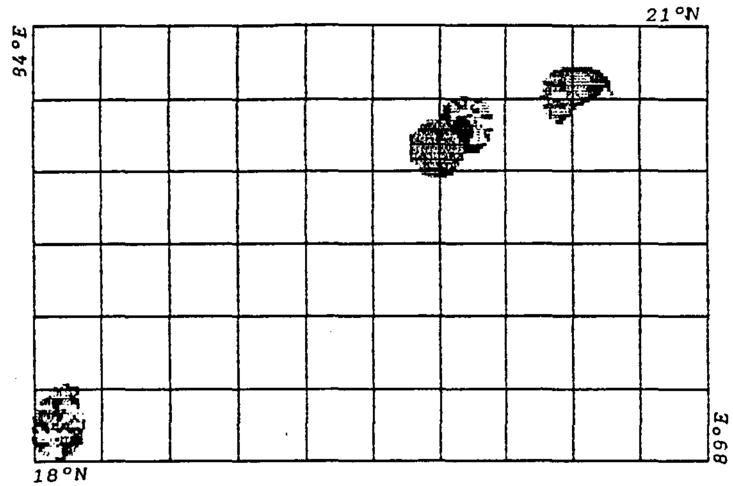


Fig. 4.169 Spatial distribution of Caranx during April

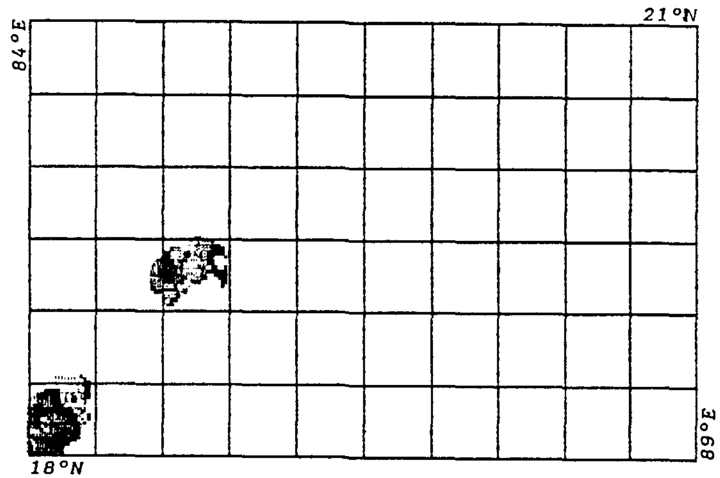


Fig. 4.170 Spatial distribution of Caranx during May

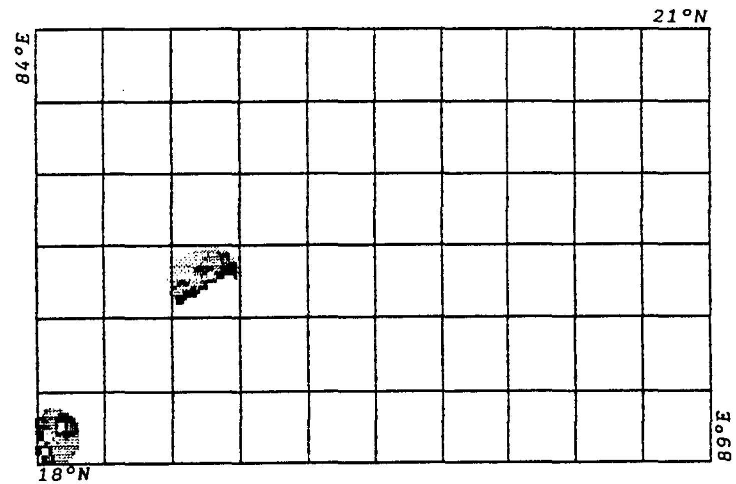


Fig. 4.171 Spatial distribution of Caranx during June

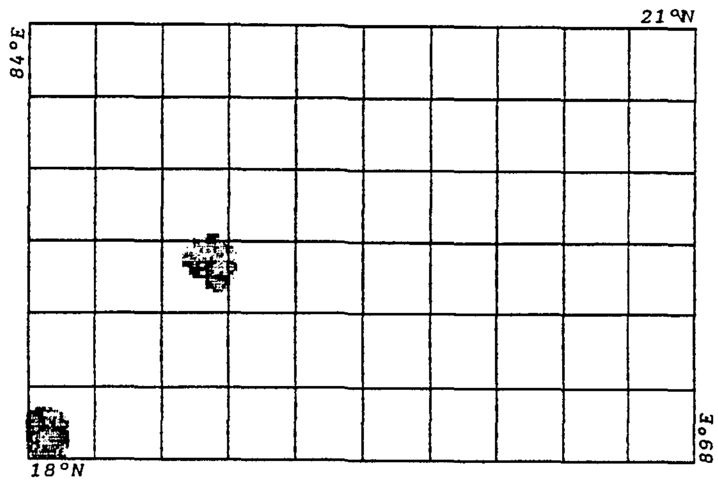


Fig. 4.172 Spatial distribution of Caranx during July

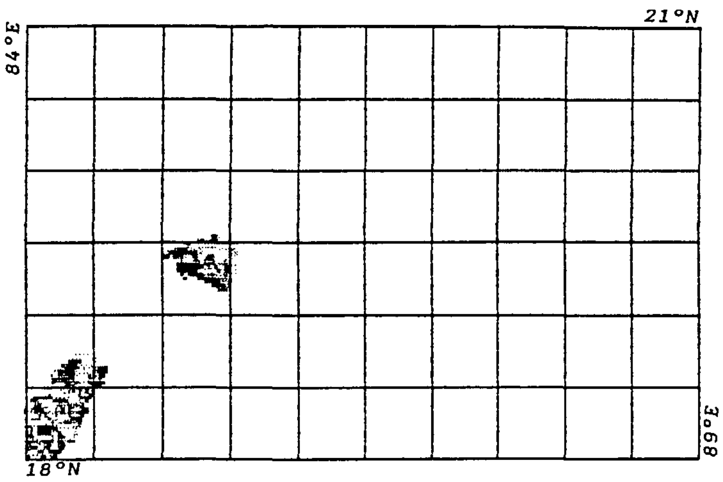


Fig. 4.173 Spatial distribution of Caranx during August

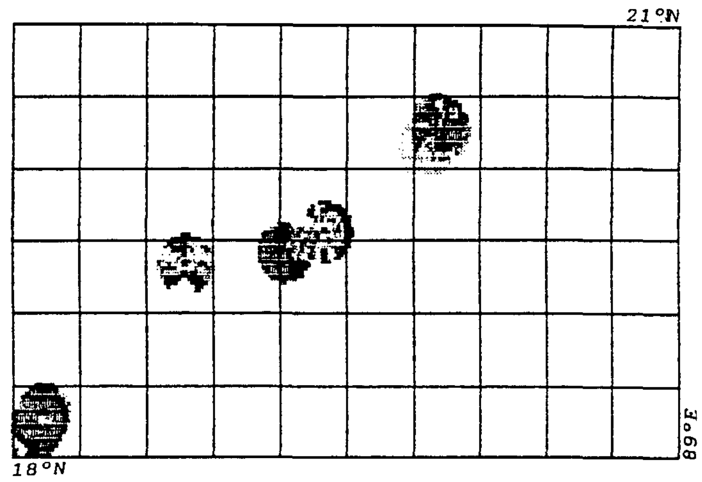


Fig. 4.174 Spatial distribution of Caranx during November

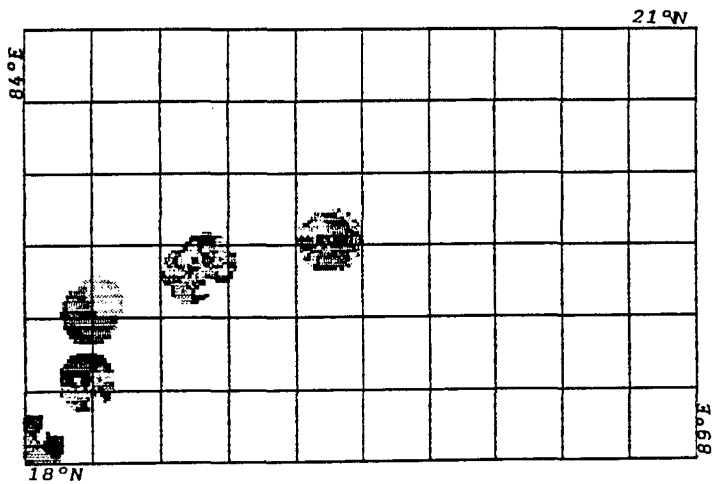


Fig. 4.175 Spatial distribution of Caranx during December

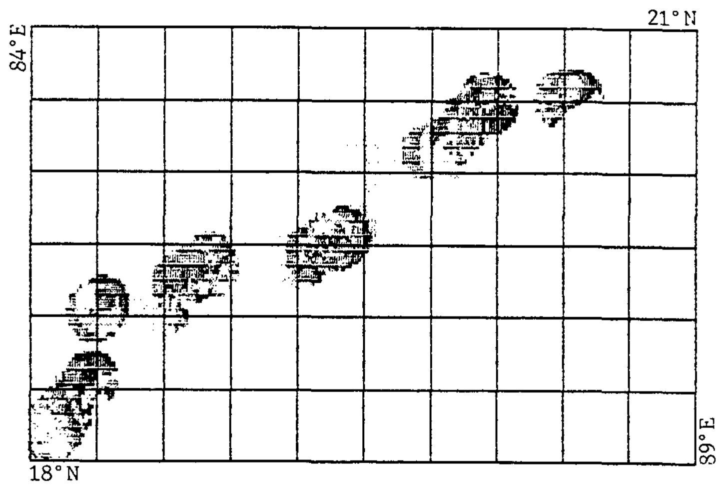


Fig. 4.176

TOTAL ANNUAL DISTRIBUTION OF CARANX IN NORTH WEST BAY OF BENGAL

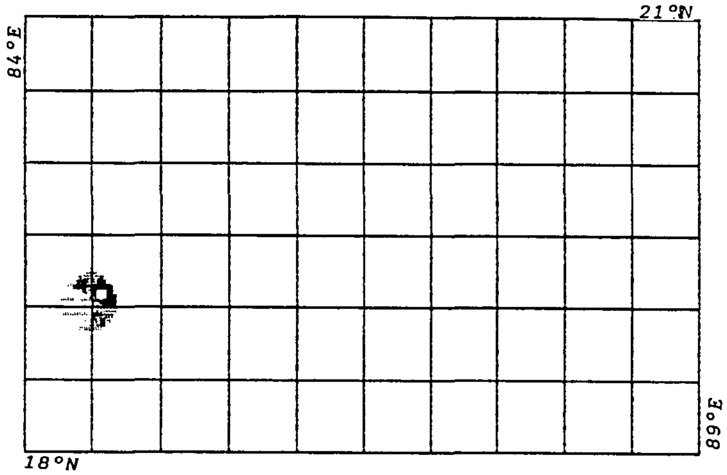


Fig. 4.177 Spatial distribution of Chorinemus during March

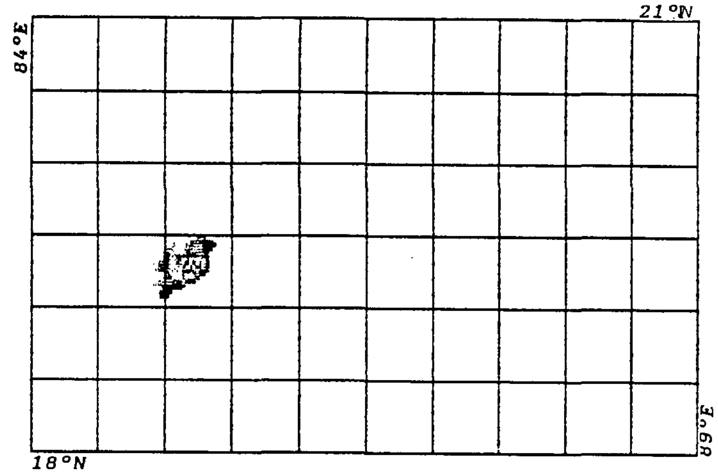


Fig. 4.178 Spatial distribution of Chorinemus during May

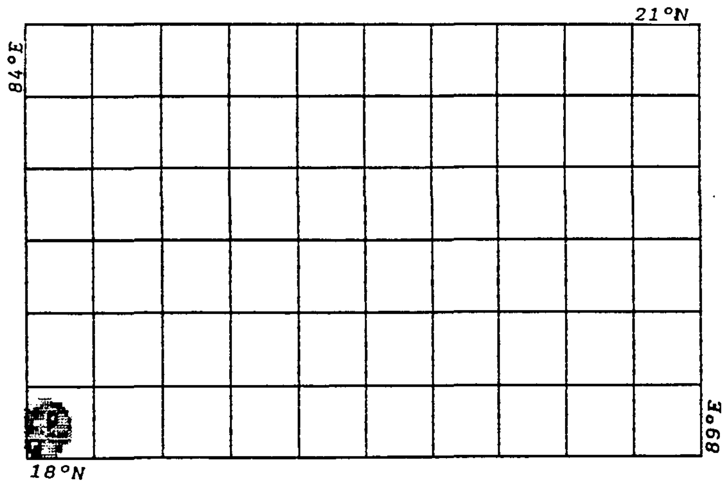


Fig. 4.179 Spatial distribution of Chorinemus during June

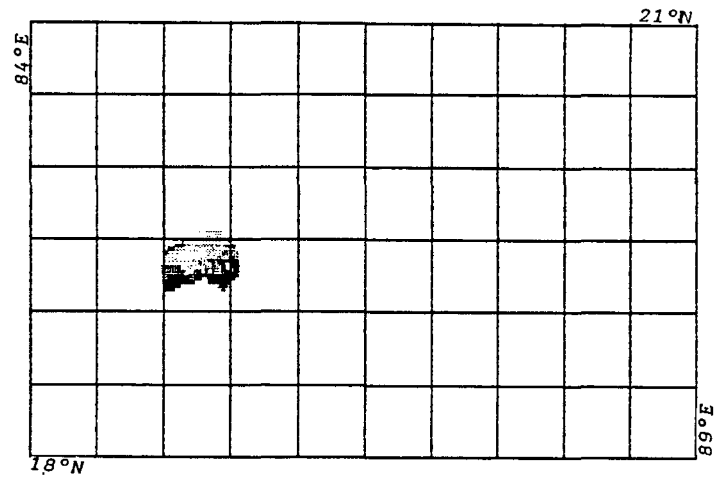


Fig. 4.180 Spatial distribution of Chorinemus during July

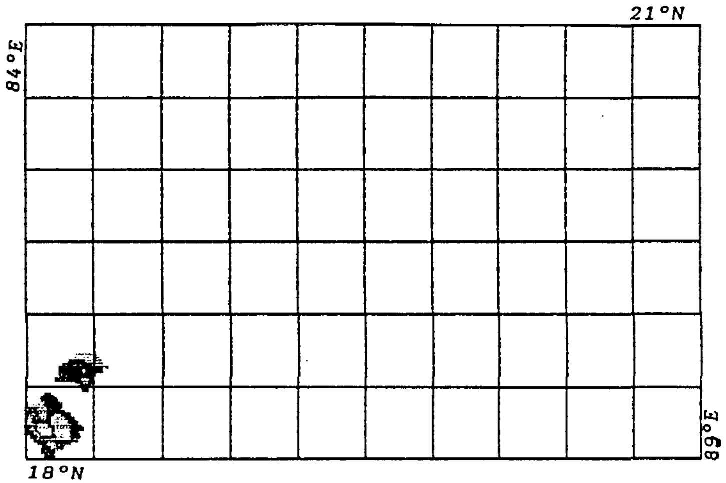


Fig. 4.181 Spatial distribution of Chorinemus during August

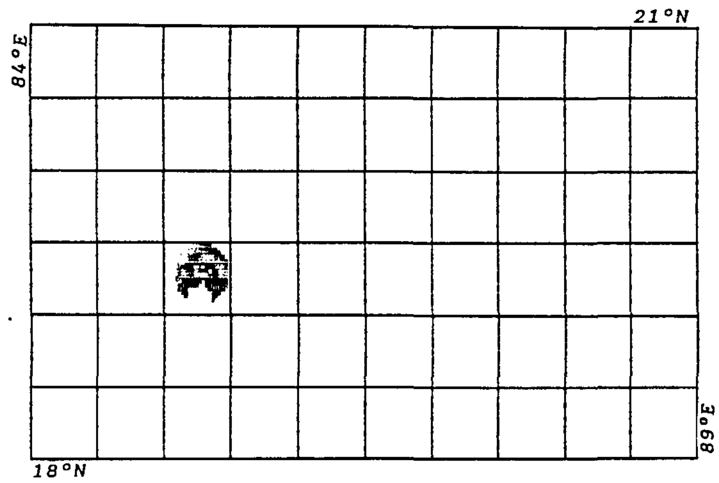


Fig. 4.182 Spatial distribution of Chorinemus during November

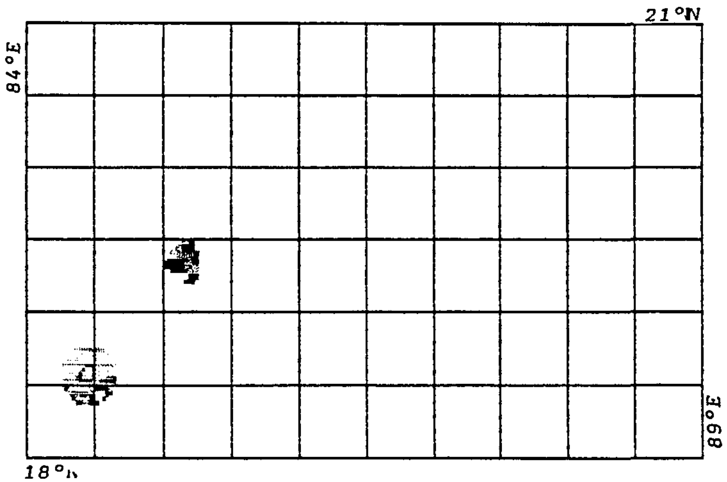


Fig. 4.183 Spatial distribution of Chorinemus during December

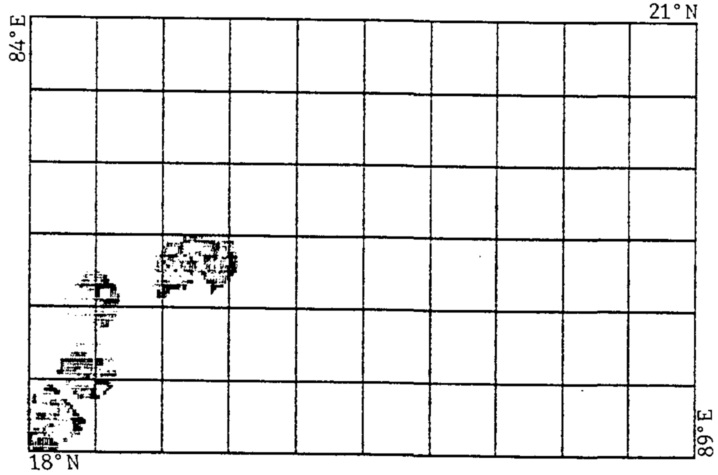


Fig. 4.184

TOTAL ANNUAL DISTRIBUTION OF CHORINEMUS IN NORTH WEST BAY OF BENGAL

4.2.23 CHORINEMUS

Chorinemus were caught in seven out of the nine month catches. They were mainly caught in areas between 18°-19°45'N and 84°-84°40'E and 19°-19°30'N and 84°55' -85°35'E (Fig. 4.177-4.184) in their month-wise and total annual distribution. The catch ranged from 0-23kg with an average catch of 11.1kg/month (Table 4.1). Chorinemus were caught in the depth range of 40-60 meters.

4.2.24 MACKERELS

Mackerels were caught in all the nine month catches. They were mainly caught in areas between 18°-18°45'N and 84°-84°40'E; 19°-19°35'N and 84°45'-85°35'E; .pa 19°15'-19°45'N and 85°50'-86°35'E; 19°50'-20°10'N and 86°20'-87°35'E and 20°30'-20°45'N and 87°50'- 88°05'E (Fig. 4.185-4.194) in their month-wise and total annual distribution. The catch ranged from 11-1441kg with an average catch of 418.7kg/month (Table 4.1). Mackerals were caught in the depth range of 30-70 meters.

4.2.25 DECAPTERIDS

Decapterids were caught in five out of nine month catches. They were mainly caught in areas between 18°-18°30'N and 84°-84°20'E; 19°-19°30'N and 85°-85°30'E; 19°50'-20°20'N and 86°50'-87°20'E and 20°05'-20°40'N and 87°50'-88°20'E (Fig. 4.195-4.200) in their month-wise and annual distribution. The

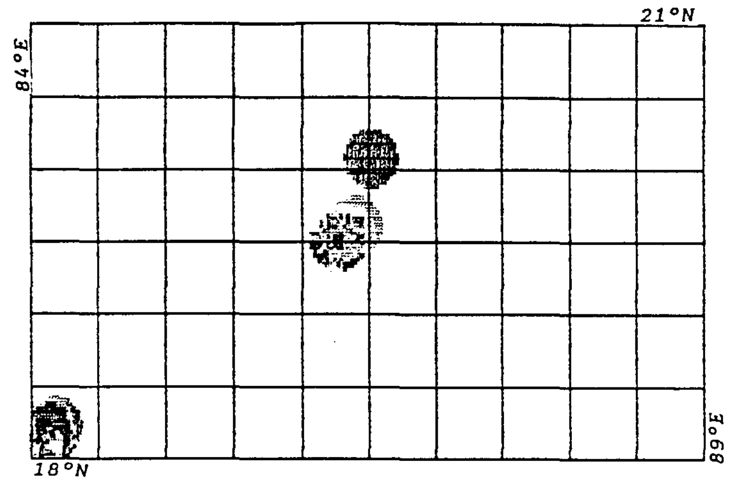


Fig. 4.185 Spatial distribution of Mackerel during February

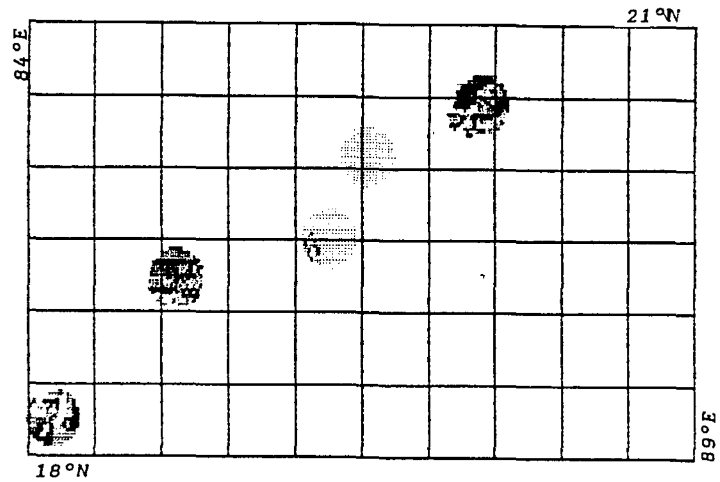


Fig. 4.186 Spatial distribution of Mackerel during March

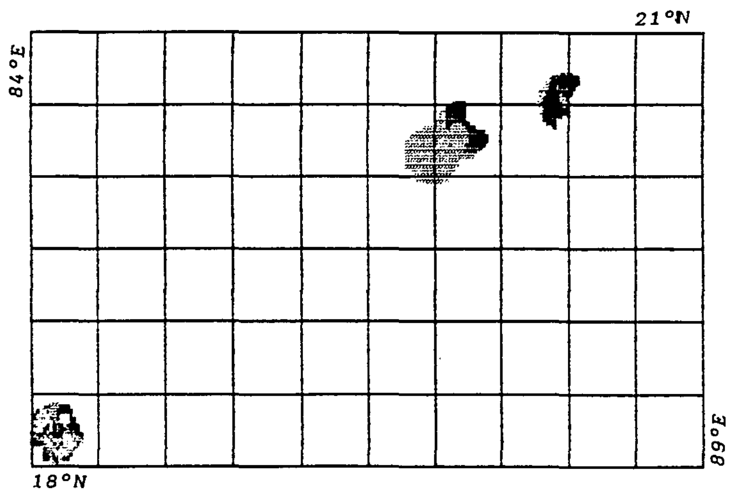


Fig. 4.187 Spatial distribution of Mackerel during April

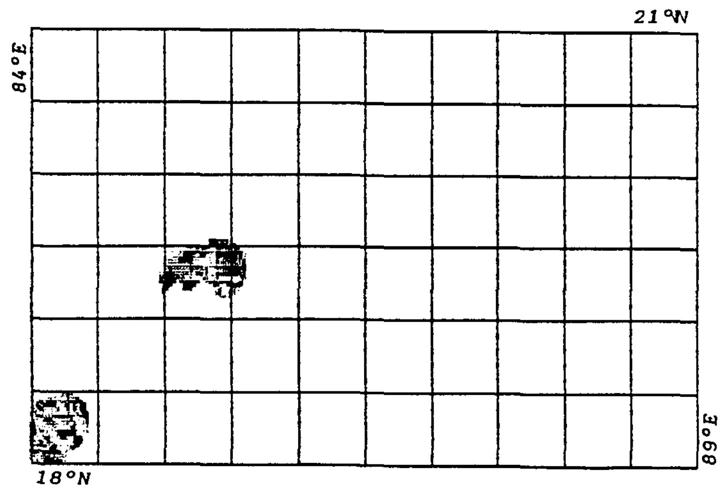


Fig. 4.188 Spatial distribution of Mackerel during May

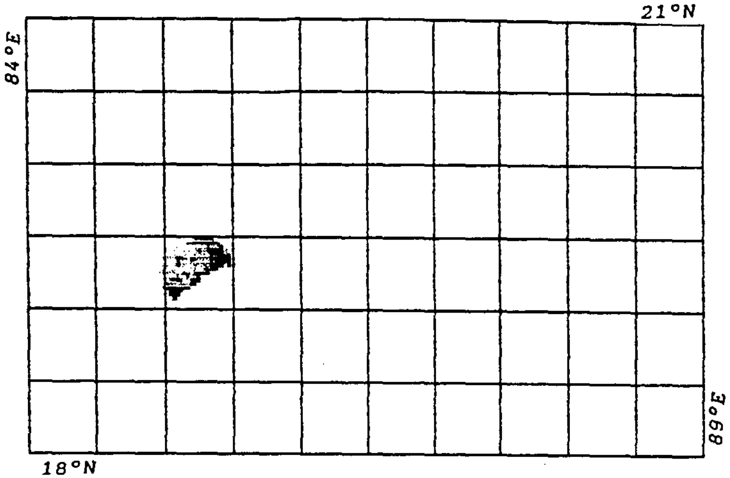


Fig. 4.189 Spatial distribution of Mackerel during June

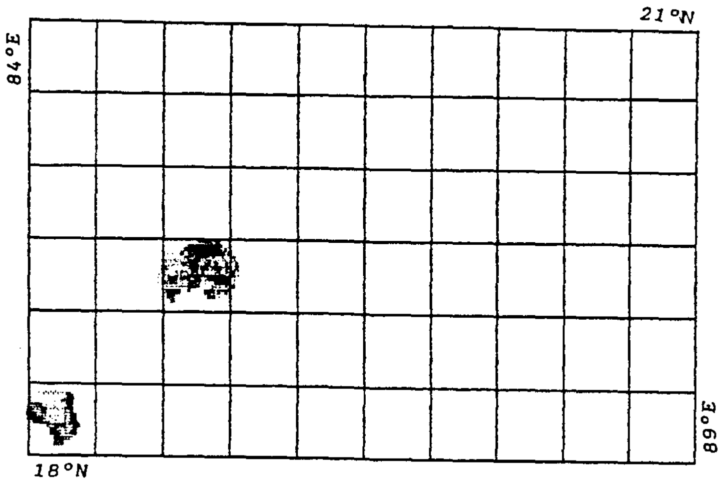


Fig. 4.190 Spatial distribution of Mackerel during July

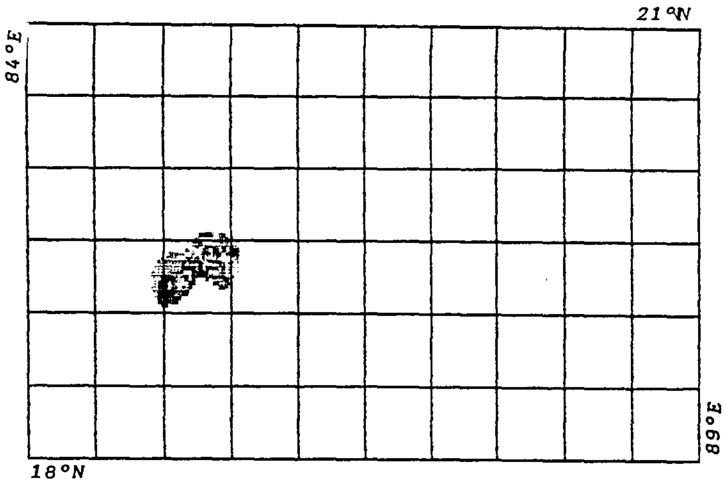


Fig. 4.191 Spatial distribution of Mackerel during August

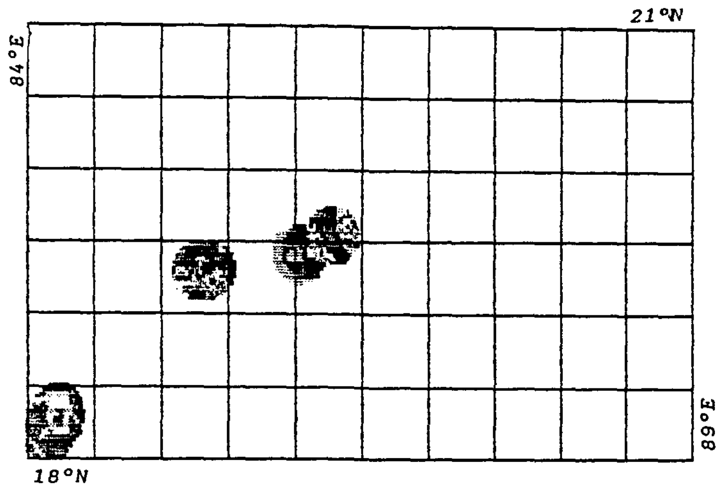


Fig. 4.192 Spatial distribution of Mackerel during November

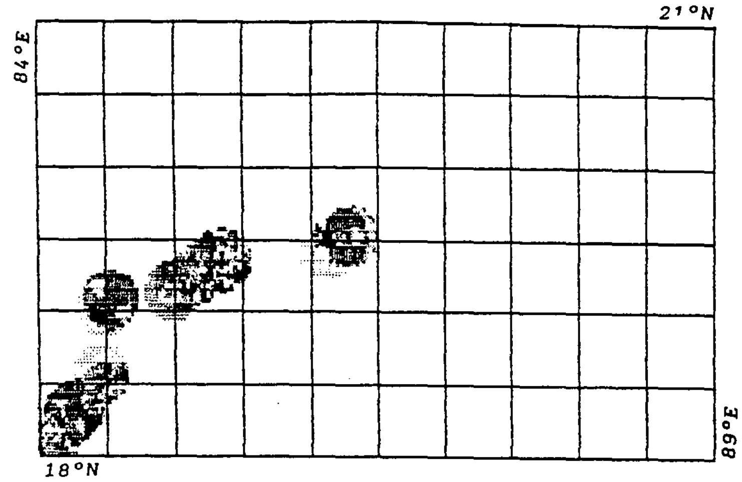


Fig. 4.193 Spatial distribution of Mackerel during December

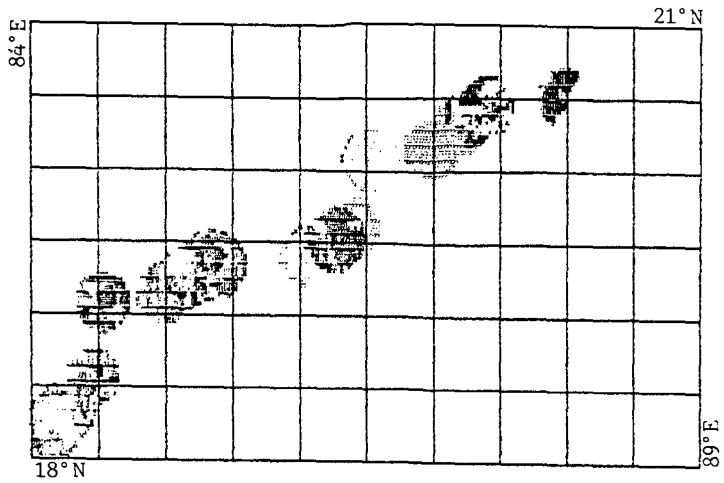


Fig. 4.194

TOTAL ANNUAL DISTRIBUTION OF MACKEREL IN NORTH WEST BAY OF BENGAL

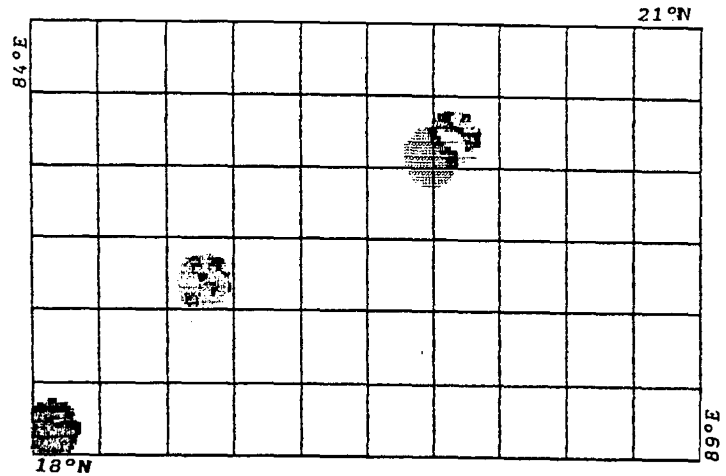


Fig. 4.195 Spatial distribution of Decapterids during February

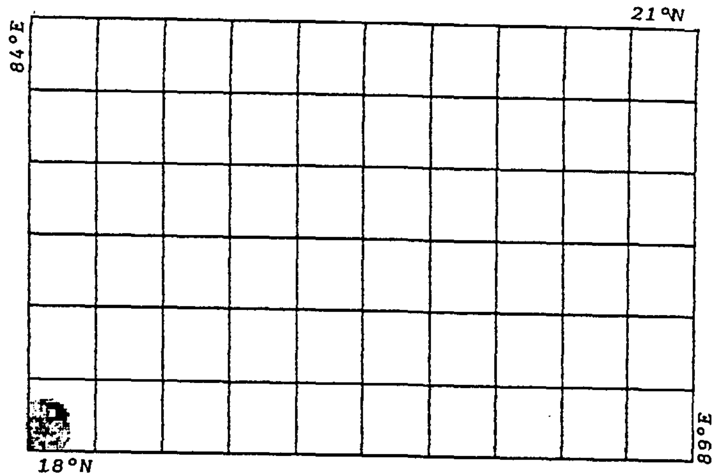


Fig. 4.196 Spatial distribution of Decapterids during March

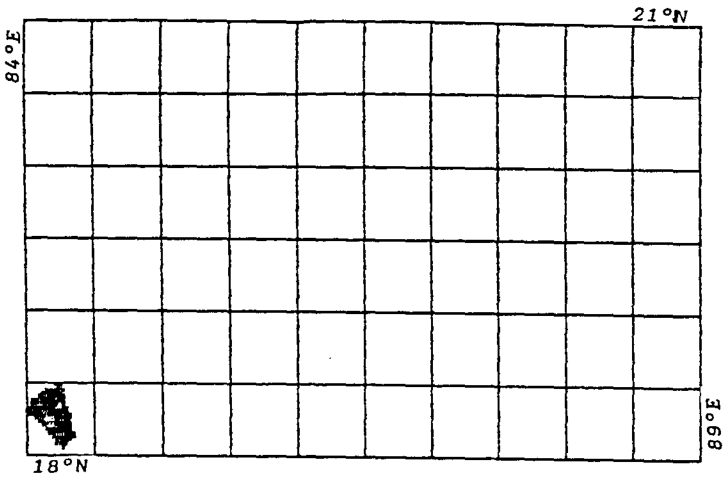


Fig. 4.197 Spatial distribution of Decapterids during April

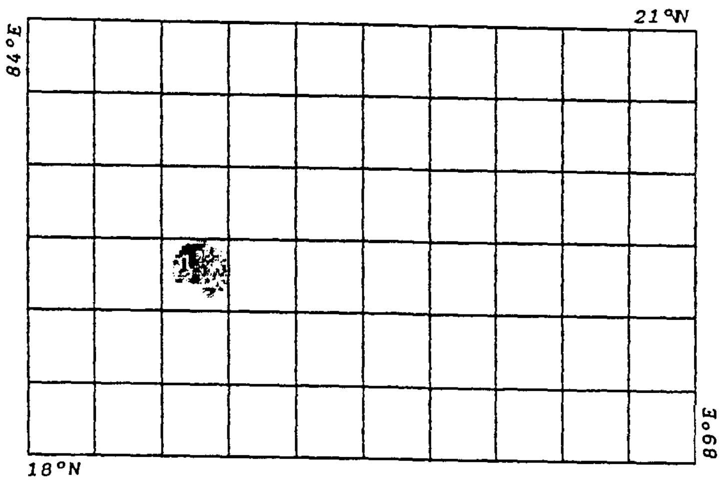


Fig. 4.198 Spatial distribution of Decapterids during July

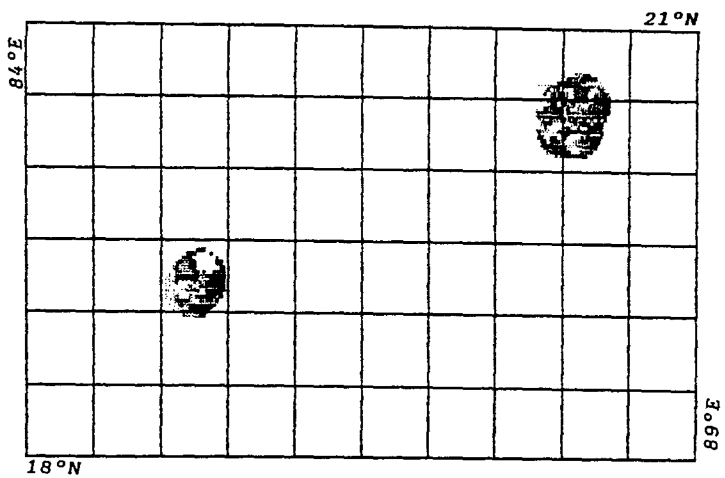


Fig. 4.199 Spatial distribution of Decapterids during November

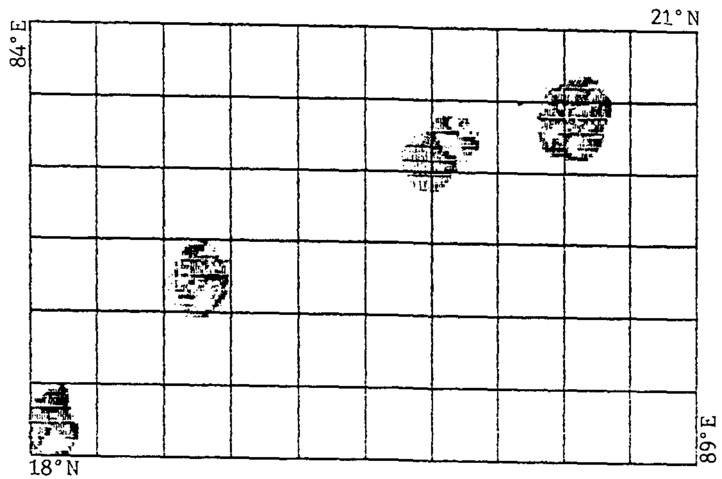


Fig. 4.200

TOTAL ANNUAL DISTRIBUTION OF DECAPTERIDS IN NORTH WEST BAY OF BENGAL catch ranged from 0-897kg with an average catch of 221.6kg/month (Table 4.1). Decapterids were caught in the depth range of 50-150 meters.

4.2.26 SEER FISHES

Seer fishes were caught in all the nine month catches. They were mainly caught in areas between 18°-18°45'N and 84°-84°35'E; 19°-19°35'N and 85°-85°35'E; 19°20'- 19°45'N and 86°-86°30'E and 20°-20°20'N and 86°50'-87°15'E (Fig. 4.201-4.209) in their month-wise and total annual distribution. The catch ranged from 1-185kg with an average catch of 59.8kg/month (Table 4.1). Seerfishes were caught in the depth range of 30-70 meters.

4.2.27 CHIROCENTRUS

Chirocentrus were caught in six out of nine month catches. They were mainly caught in areas between 18°-18°20'N and 84°-84°20'E; 19°-19°25'N and 84°45'-85°15'E; 19°15'- 19°45'N and 85°50'-86°30'E and 19°50'-20°40'N and 86°50'- 87°30'E (Fig. 4.210-4.216) in their month-wise and total annual distribution. The catch ranged from 0-32kg with an average catch of 8.8kg/month (Table 4.1). Chirocentrus were caught in the depth range of 30-70 meters.

4.2.28 SILVER BELLIES

Silver bellies were caught in five out of the nine month

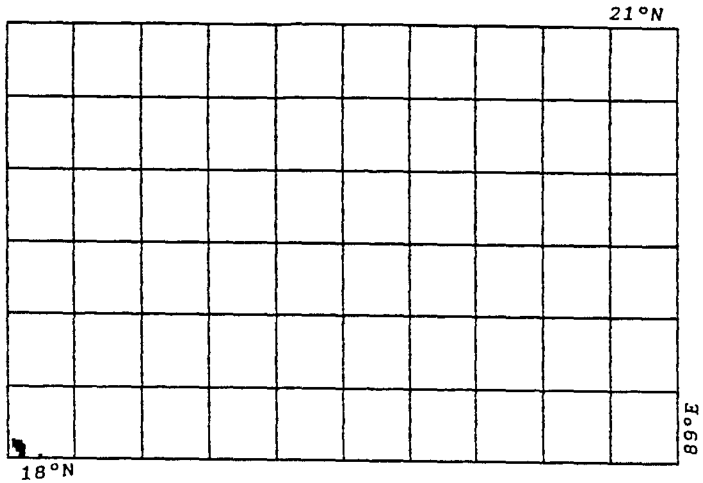


Fig. 4.201 Spatial distribution of Seer fish during February

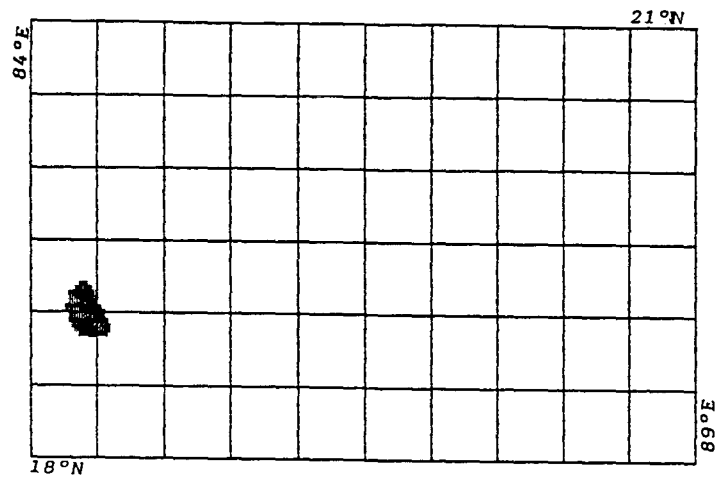


Fig. 4.202 Spatial distribution of Seer fish during March

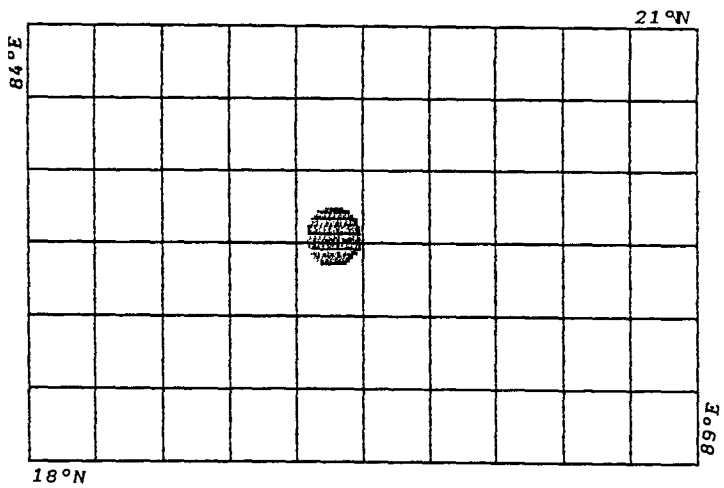


Fig. 4.203 Spatial distribution of Seer fish during April

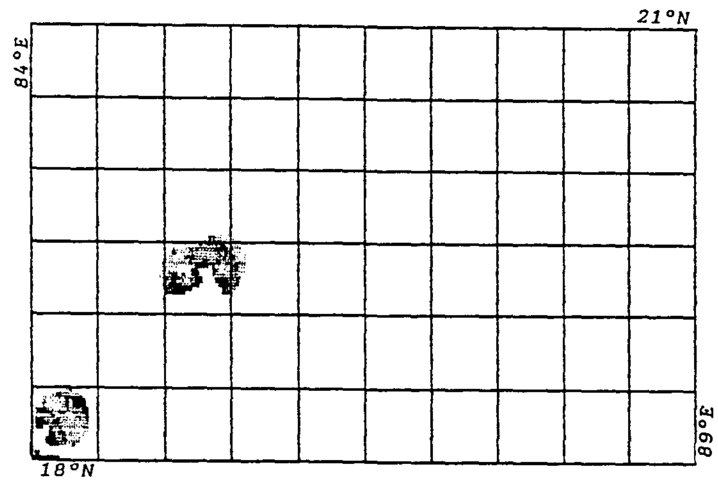


Fig. 4.204 Spatial distribution of Seer fish during May

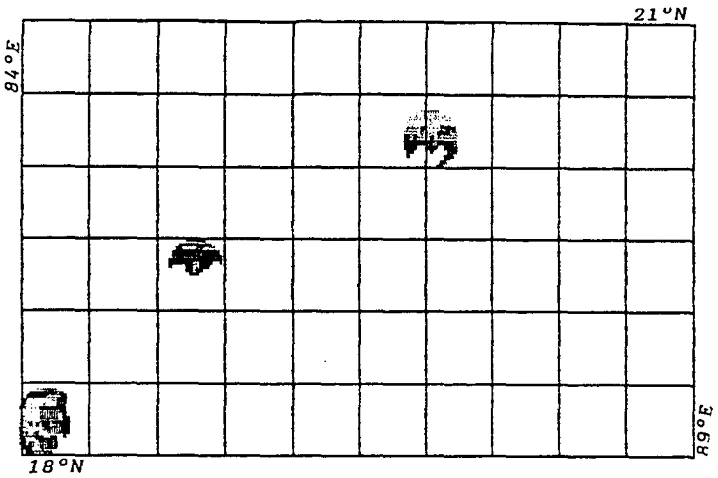


Fig. 4.205 Spatial distribution of Seer fish during June

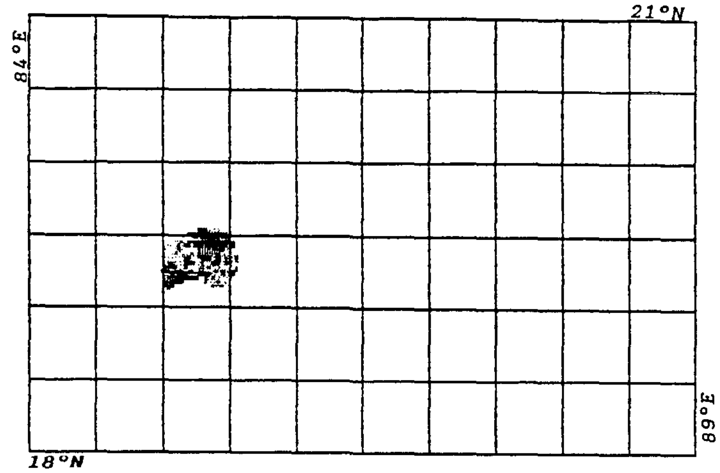


Fig. 4.206 Spatial distribution of Seer fish during July

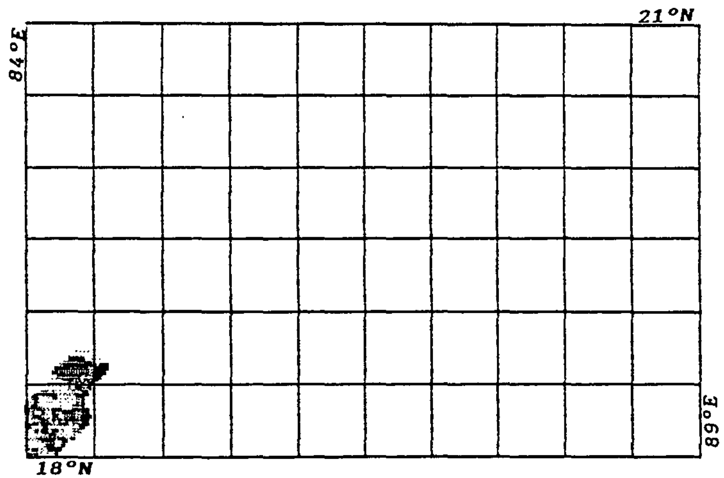


Fig. 4.207 Spatial distribution of Seer fish during August

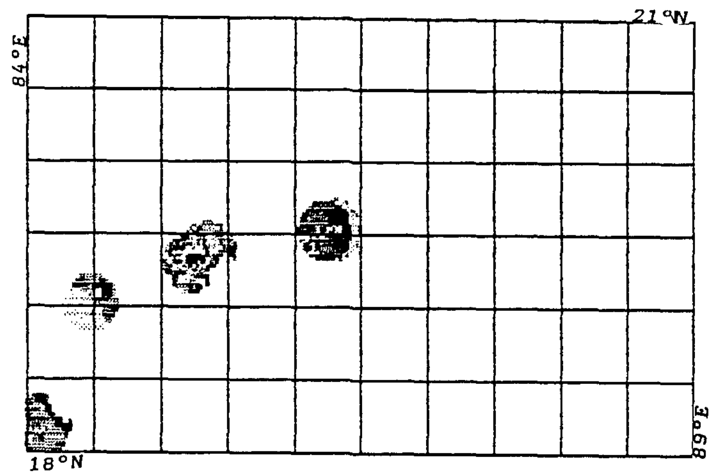


Fig. 4.208 Spatial distribution of Seer fish during December

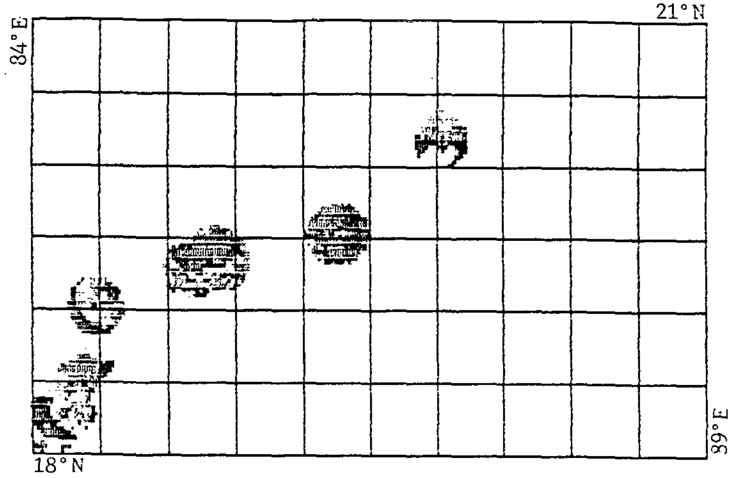


Fig. 4.209

TOTAL ANNUAL DISTRIBUTION OF SEER FISH IN NORTH WEST BAY OF BENGAL

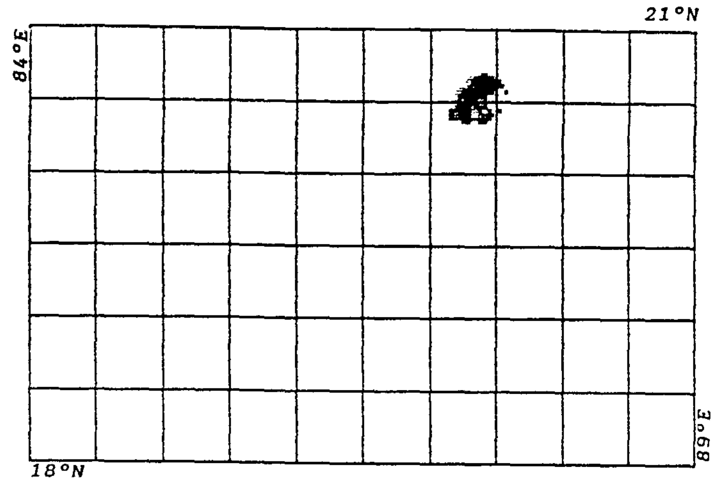


Fig. 4.210 Spatial distribution of Chirocentrus during March

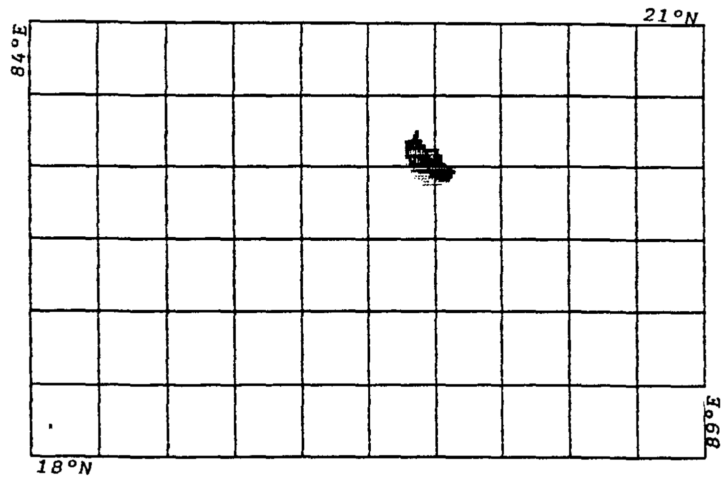


Fig. 4.211 Spatial distribution of Chirocentrus during June

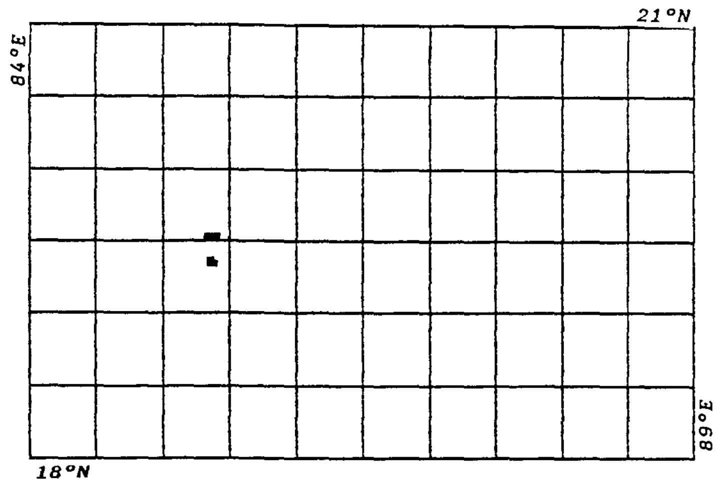


Fig. 4.212 Spatial distribution of Chirocentrus during July

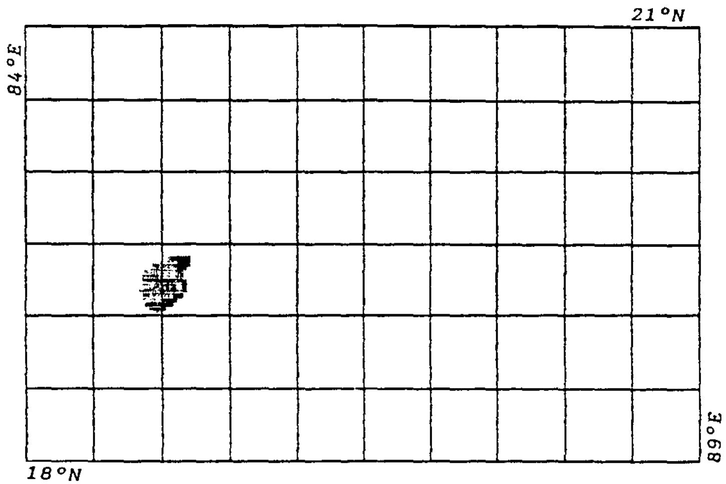


Fig. 4.213 Spatial distribution of Chirocentrus during August

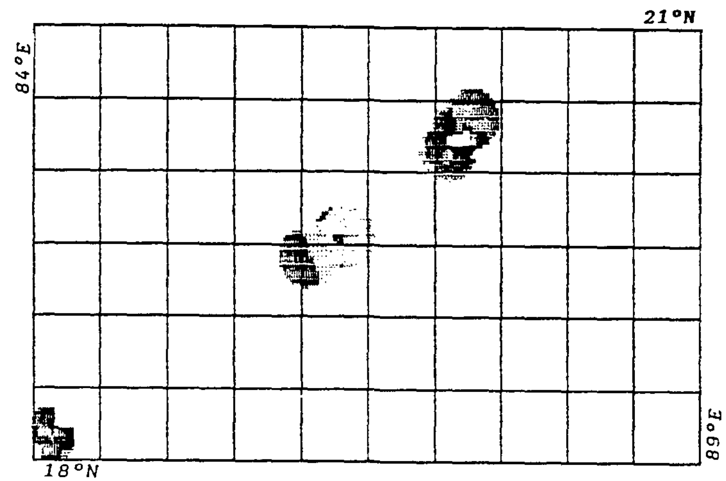


Fig. 4.214 Spatial distribution of Chirocentrus during November

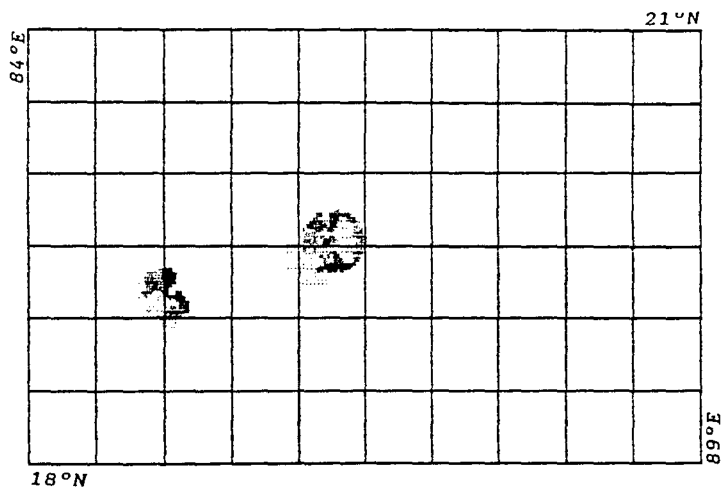


Fig. 4.215 Spatial distribution of Chirocentrus during December

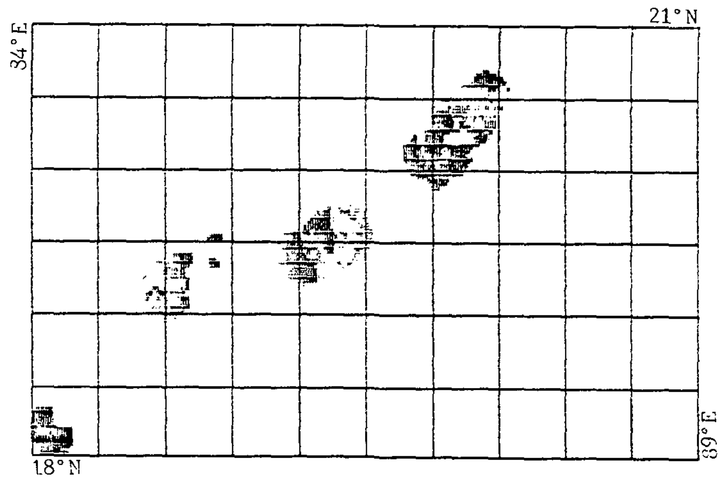


Fig. 4.216

TOTAL ANNUAL DISTRIBUTION OF CHIROCENTRUS IN NORTH WEST BAY OF BENGAL

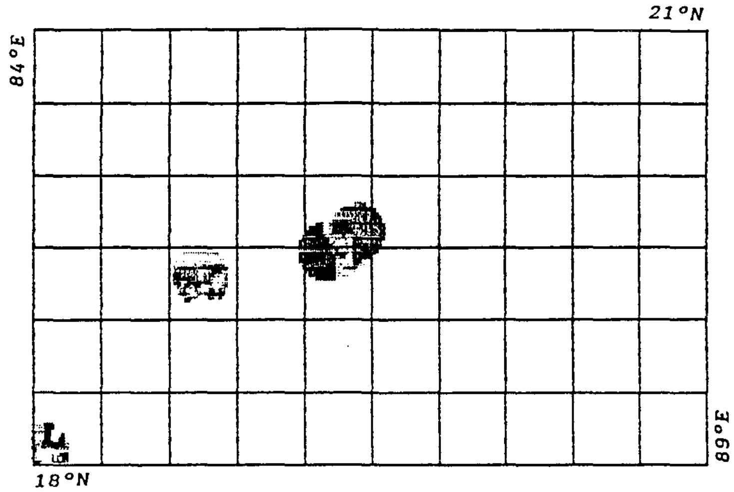


Fig. 4.217 Spatial distribution of Silverbelly during February

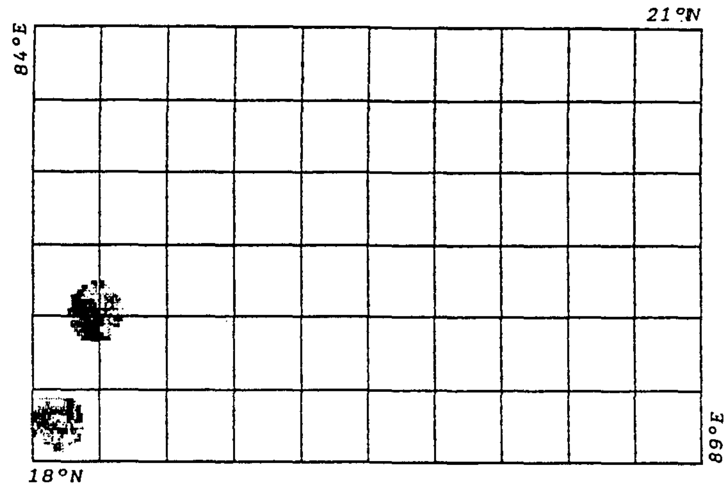


Fig. 4.218 Spatial distribution of Silverbelly during March

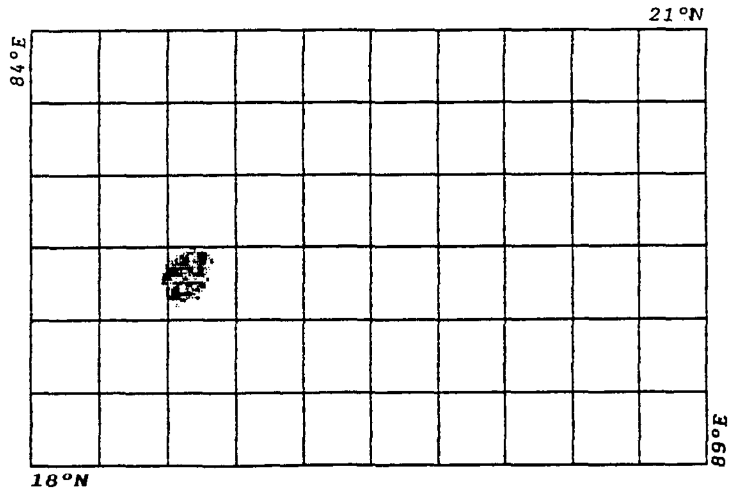


Fig. 4.219 Spatial distribution of Silverbelly during May

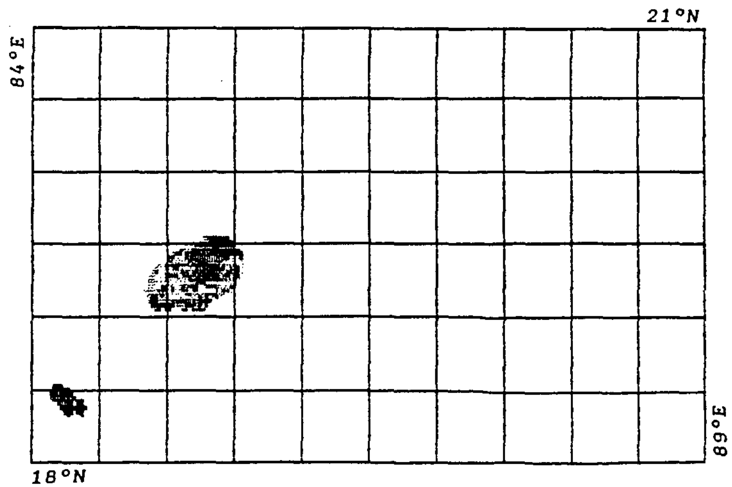


Fig. 4.220 Spatial distribution of Silverbelly during August

catches. They were mainly caught in areas between 18°-18°30'N and 84°50'-85°30'E and 19°15'-19°45'N and 86°-86°35'E (Fig. 4.217-4.221) in their month-wise and total annual distribution. The catch ranged from 0-1166kg with an average catch of 179.1kg/month (Table 4.1). Silver bellies were caught in the depth range of 30-70 meters.

4.2.29 SQUIDS

Squids were caught in eight out of the nine month catches. They were mainly caught in areas between 18°-18°40'N and 84°45'-85°40'E; 19°15'-19°45' and 86°45'-87°20'E and 20°20'-20°45'N and 87°20'-88°15'E (Fig. 4.222-4.230) in their month-wise and total annual distribution. The catch ranged from 0-350kg with an average catch of 105.1kg/month (Table 4.1). Squids were caught in the depth range of 30-80 meters.

4.3 Diversity in Fish Population

An interesting diversity was observed in the fish species present during the fish catches in various months. Few dominant fish species in north-west Bay of Bengal as observed in fish catches during February to December are given below:

4.3.1 FEBRUARY

In February the dominant fish species were catfishes, nemipterids, carangids, mackerels, decapterids and ribbon fishes. These fishes formed 84.9% of the total catch of 6445kg.

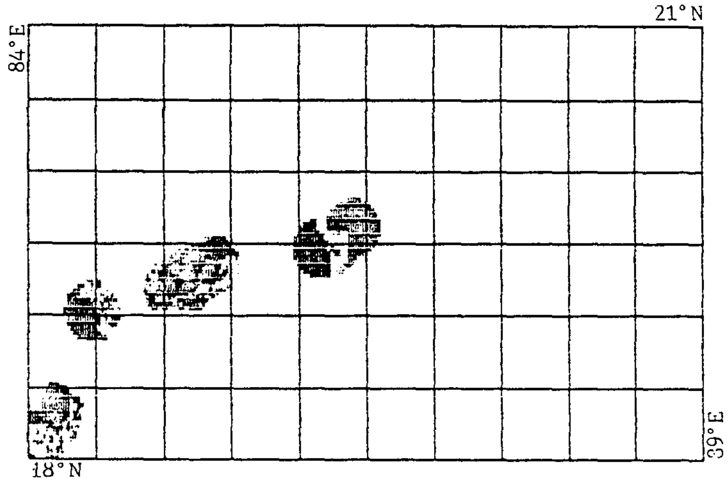


Fig. 4.221

TOTAL ANNUAL DISTRIBUTION OF SILVERBELLY IN NORTH WEST BAY OF BENGAL

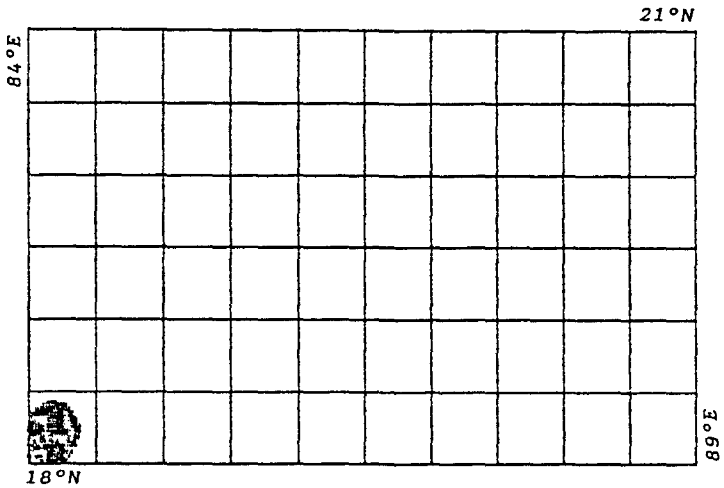


Fig. 4.222 Spatial distribution of Squid during February

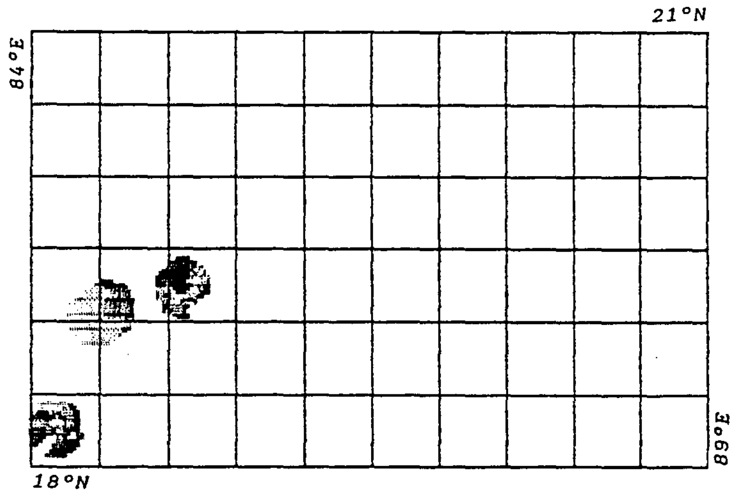


Fig. 4.223 Spatial distribution of Squid during March

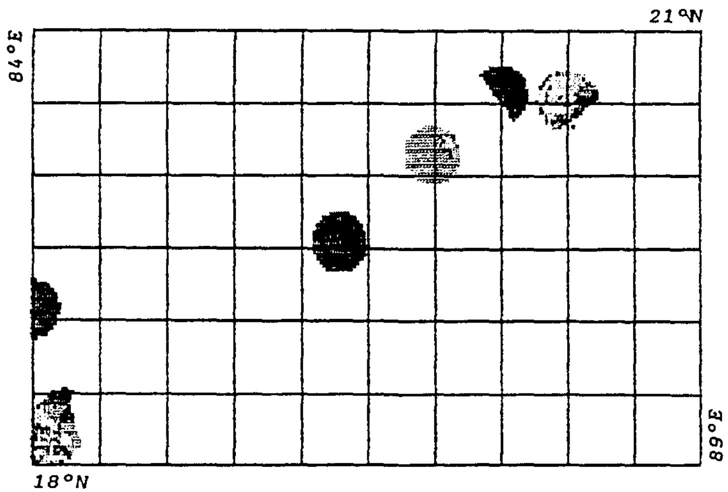


Fig. 4.224 Spatial distribution of Squid during April

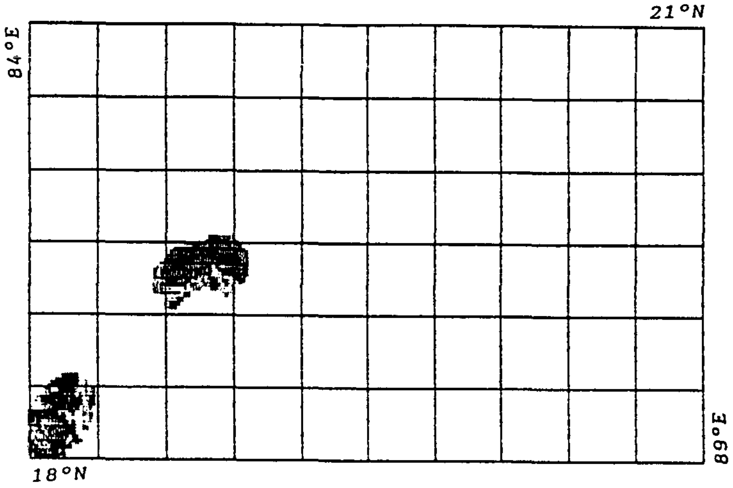


Fig. 4.225 Spatial distribution of Squid during May

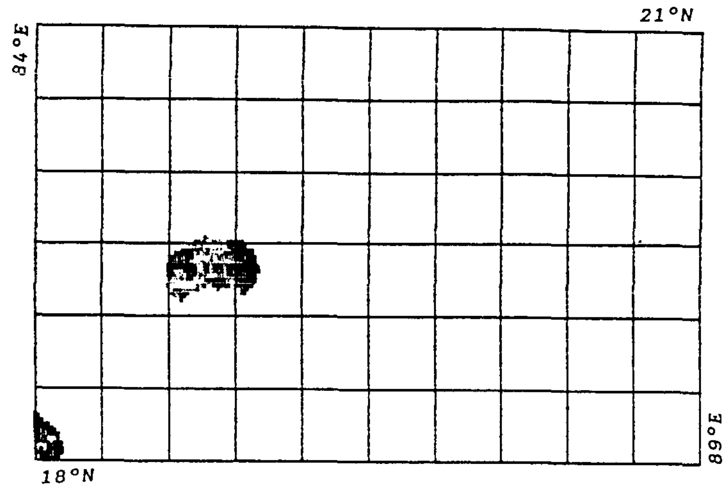


Fig. 4.226 Spatial distribution of Squid during July

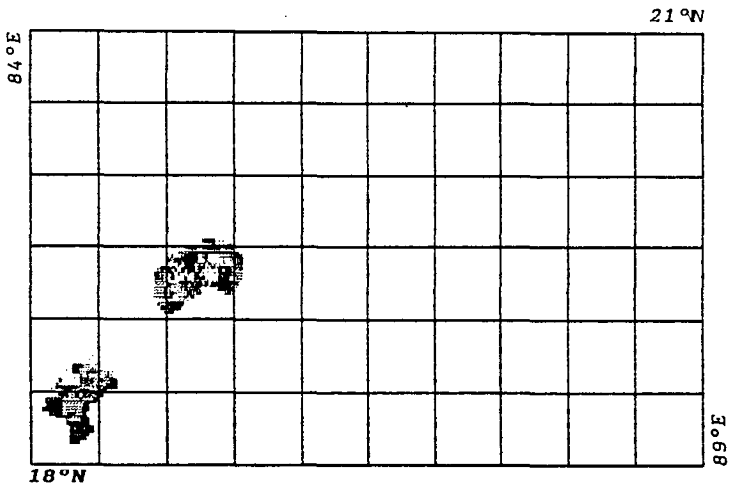


Fig. 4.227 Spatial distribution of Squid during August

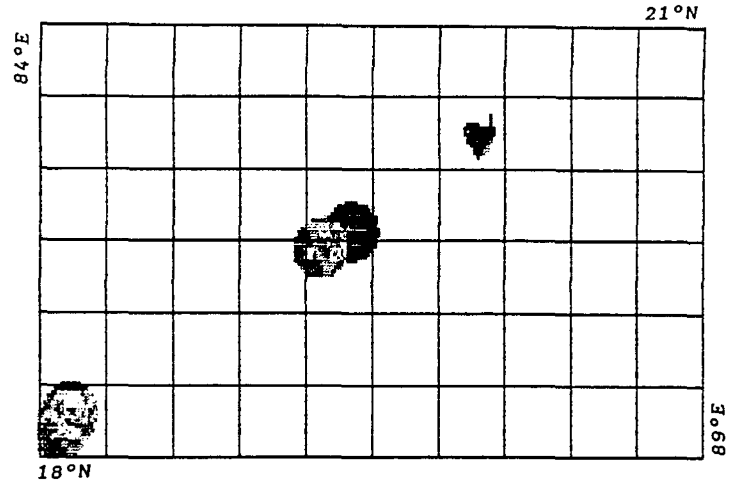


Fig. 4.228 Spatial distribution of Squid during November

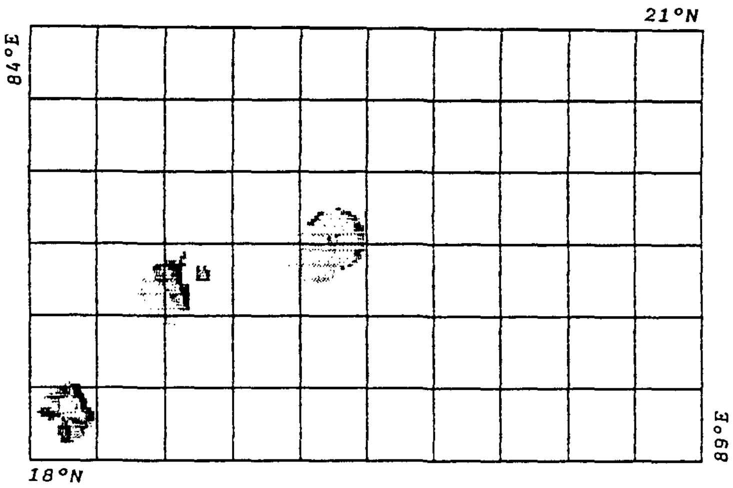


Fig. 4.229 Spatial distribution of Squid during December

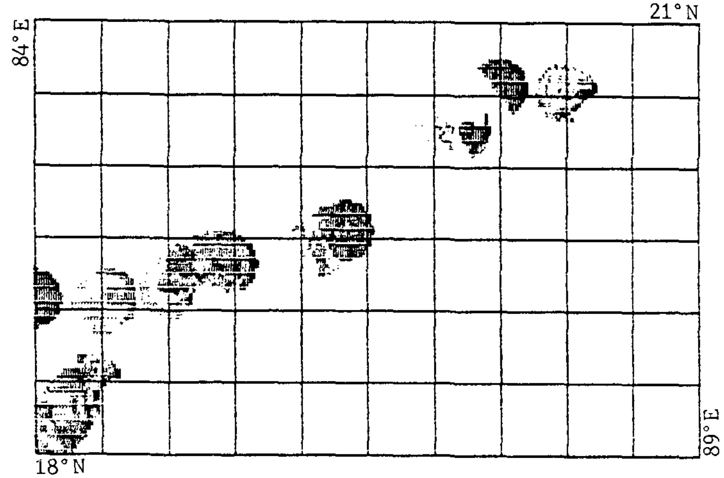


Fig. 4.230

TOTAL ANNUAL DISTRIBUTION OF SQUID IN NORTH WEST BAY OF BENGAL

4.3.2 MARCH

Dominant fish species were psenus, catfishes, mackerels, carangids, silver bellies, dhoma and nemipterids. These fishes formed 78.8% of the total catch of 5395kg.

4.3.3 APRIL

Dominant fish species in the catches were catfishes, upenoids, decapterids and karkaras. These fishes formed 69.5% of the total catch of 4591kgs.

4.3.4 MAY

Dominant fish species in the catches were leognathids, nemipterids, lizard fishes and priacanthus. These fishes formed 47.6% of the total catch of 6471kgs.

4.3.5 JUNE

Dominant fish species in the catches were nemipterids, leognathids, priacanthus and upenoids. These fishes formed 71% of the total catch of 4173Kgs.

4.3.6 JULY

Dominant fish species in the catches were mackerel, catfish, nemipterids and psenus. These fishes formed 59.7% of the total catch of 7470kgs.

4.3.7 AUGUST

Dominant fish species in the catches were silver bellies, clupeids, ribbon fishes and pomfret. These fishes formed 74% of the total catch of 3557kgs.

4.3.8 NOVEMBER

Dominant fish species observed in the catches were nemipterids, leognathids, catfishes and priacanthus. These fishes formed 63.7% of the total catch of 11150kgs.

4.3.9 DECEMBER

Dominant fish species found in the catches were upenoids, mackerels, karkaras, nemipterids and leognathids. These fishes formed 71.6% of the total catch of 6443kgs.

4.4 Gridwise Indices and Spatio-temporal trends

4.4.1 ZONATION

When observed, almost all the fish species were found in the areas between 18°-18°30'N and 84°-84°30'E. Forming a high concentration (Z1) zone (Fig. 4.231). There is an upward moving trend for the fishes distributing themselves fairly in the entire region. The second richest zone in terms of fish concentration (Z2) is an area between 20°-20°30'N and 87°-88°30'E (Fig. 4.231).

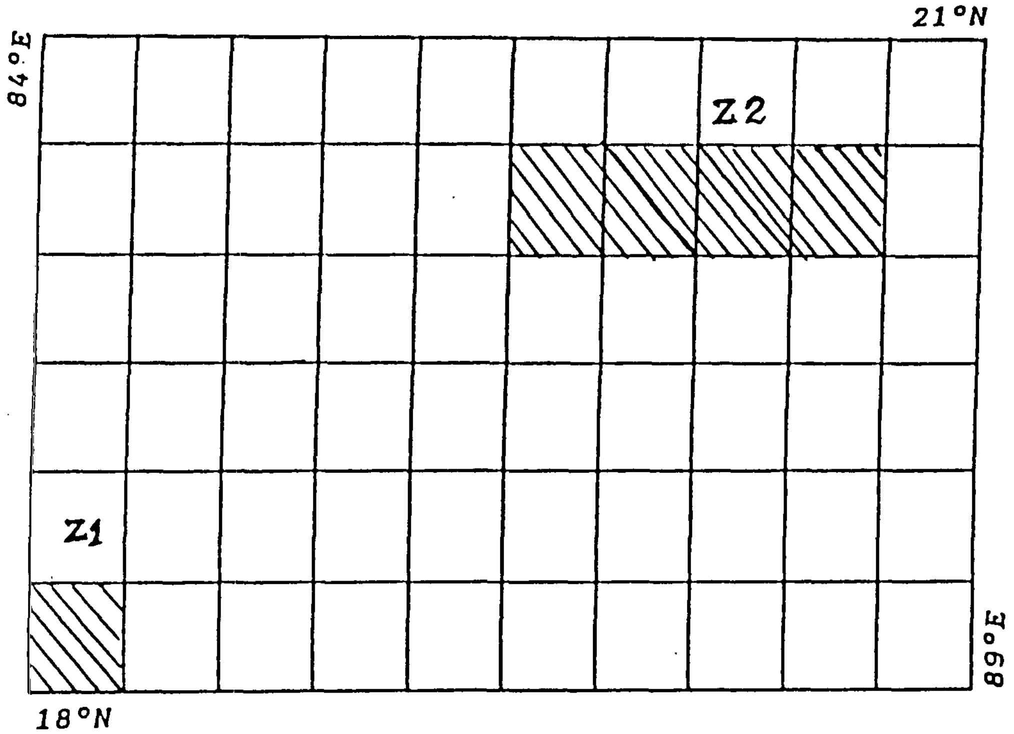


Fig. 4.231 High Concentration zones as observed through Fish catches.

Presence or occurrence of different fish species are observed to vary from month to month or season to season. Moreover, the presence of various fish species also varies from depth to depth.

4.4.2 INTERSPECIES RELATIONSHIP

It was interesting to observe that som always in combination with some species. taken as indicator species for the informati other fish species present in the area. Som combinations (Fig. 4.232) observed for a few follows:

How was this analys made? To what extent the readers ca ~~cons the~~ believe these ~~objective~~ i. terms of objectivity In other words, this may be a good chance for suio...

1. Pomfret + Catfish + Karkara.
2. Nemipterids + Upenoids
3. Ray + Skate + Chirocentrus + Eel
4. Cuttle + Squid + Mackerel + Carangids

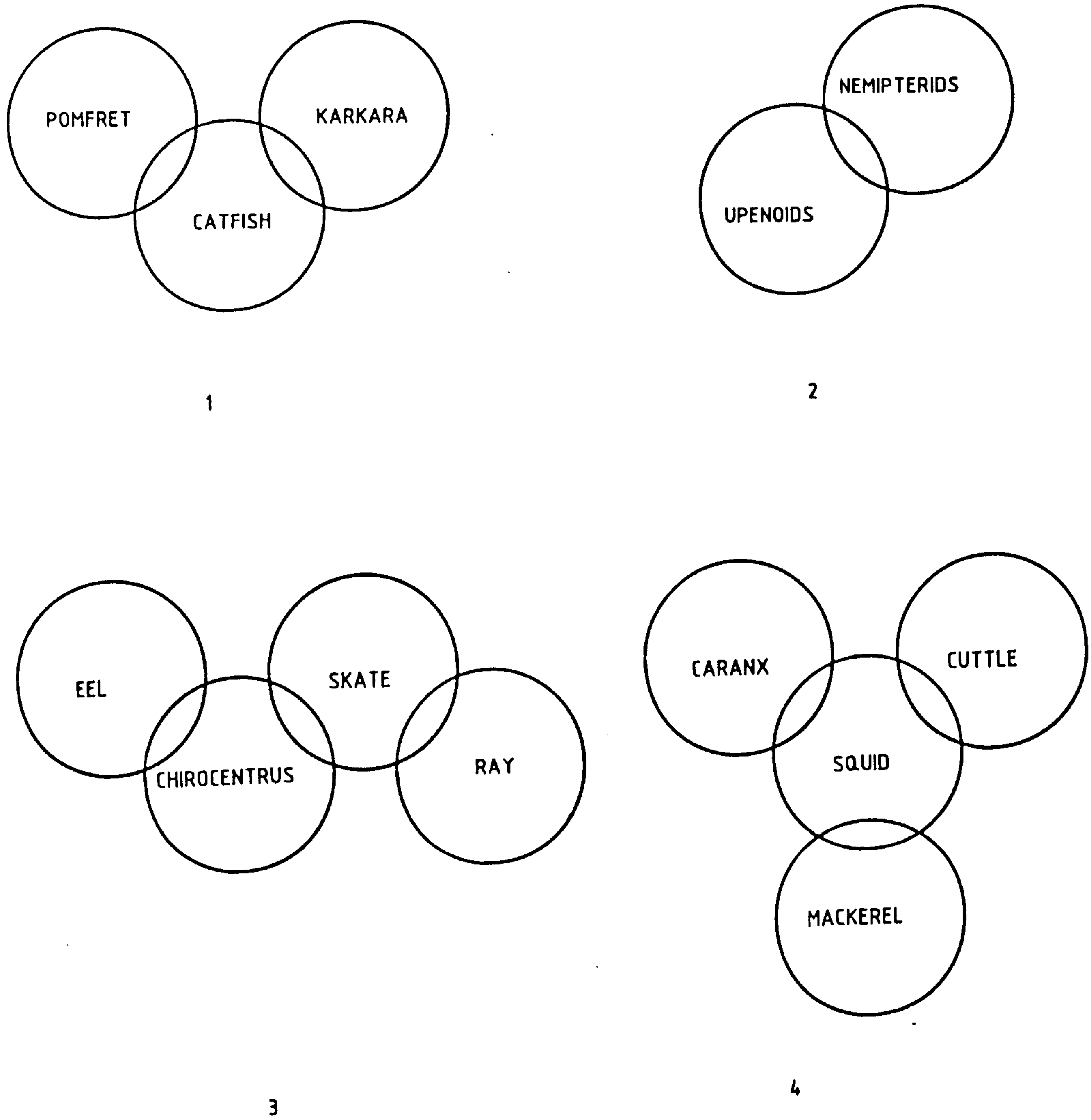


Fig. 4.232 SOME COMMON FISH SPECIES COMBINATIONS (1-4).

CHAPTER FIVE

ANALYSIS OF SPATIAL SCALES OF PROCESSES IN THE FISHERIES ENVIRONMENT

5.0 SPATIAL SCALES OF PROCESSES IN THE FISHI

Words wrap around without hyphenation
pp 183-185

Fisheries environment in coastal zone various processes like ocean and coastal circ (Industrial, Thermal, Agriculture, etc.), bath mangrove vegetation, estuarine ecosystem, coa lagoons and creeks, human activity, etc. Fig. schematic sketch of different features in Every environment has a unique feature with scales. Processes may be micro, meso or mega scale processes.

The heterogenity in the distribution of these spatial scale of features is mainly dependent on ocean circulation and various other hydro-dynamic processes, which affects the biological pro ductivity. Satellite derived spatial scale information can be used to identify the physical processes affecting biomass distri bution such as currents, upwelling, temperature, fronts and pollution. These ocean features generally form and dissipate within relatively short periods (days, weeks or months).

The time-space variability at these scales affects the growth and survival of zooplankton, larval fish and adult fish. It is necessary to note the difference between physical and biological phenomenon. The physical processes like internal waves, tidal mixing and storms are clearly demarcated on temporal

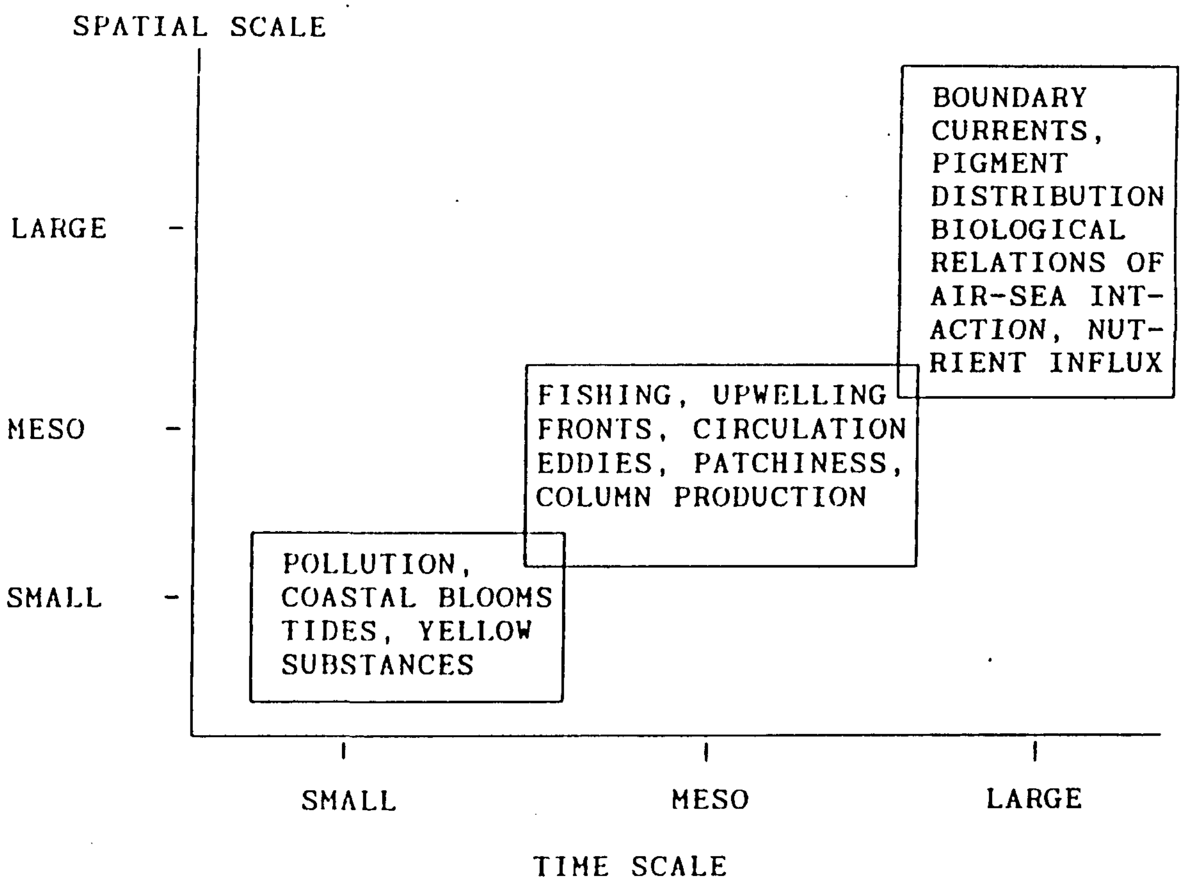


Fig. 5.1 Schematic Sketch of different features in the coastal zone.

scale and are spatially wide features with sharp temporal limitations. The biological phenomena have an intricate overlapping pattern and are operative on a broad time space continuum (Sudar shana, 1986). Ship can directly detect many oceanographic fea tures except for a few which have very small temporal existance.

Fig. 5.2 explains the biological patterns in the ocean and their driving mechanism to occupy higher spatial scale in com parison to the scale of components. It is evident that the bio logical features like phytoplankton, zooplankton and nekton are small scale features which eventually become global processes in terms of occurance and influence. Thus, their physiological response to water quality, their population dynamics and trophic interactions becomes a matter of global proportion requiring a synoptic approach in sampling and monitoring. Accuracy and coverage of different sensors that apply to oceanographic re search are also projected in Fig. 5.2.

Basically, statistical techniques were developed to deter mine the spatial scales of features by a group of mining engi neers for their mineral exploration studies. The technique in volves calculation of semi-variance.

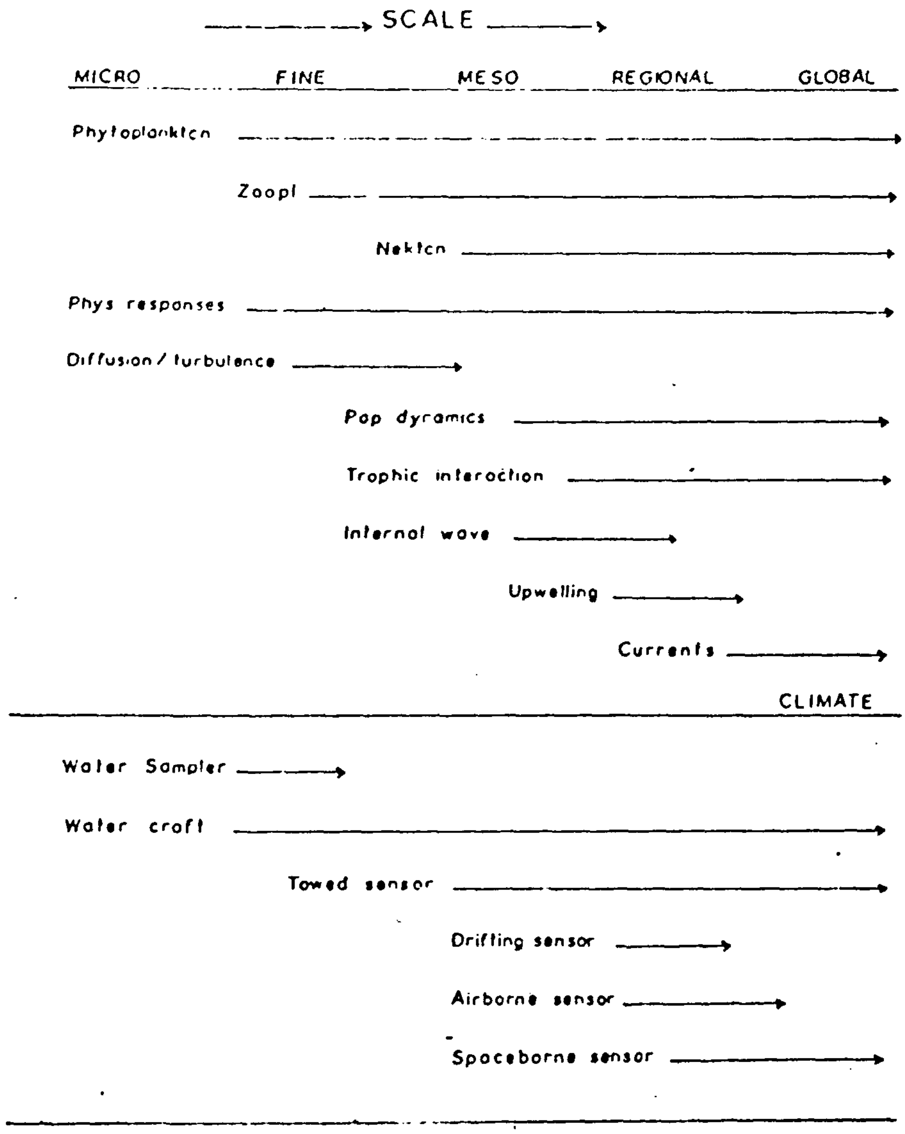


Fig. 5.2 Schematic of biological pattern, driving capability and sampler efficiency (redrawn from ESA BR-20, 1984)

5.1 Semi-Variance

This technique is referred to as the theory of regionalised variables in mineral deposit studies. Semi-variance (S-V) was calculated by the following formula (Clark, 1979):

$$S\text{-}V_{(n)} = [1/2^n]\ [gx - g(x+h)]^2$$

– Isn't it g(x) rather than

Where

gx = The sample value

n = number of observations for each lag.

h = distance between samples (lag distance).

Semi-variance is calculated for lag distance upto half the length of the total record which is therefore, the largest scale that can be resolved with the analysis.

5.2 Variogram

Variogram is also called as semi-variogram. Variogram is in fact represented as a simple graph in which semi-variance is plotted against the lag distance. Variograms are useful in finding spatial distribution of coastal features as they can be easily calculated and interpreted.

5.3 Derivation Of Spatial Scale From Variogram

Variograms yield information on the spatial distribution of the variables. Variogram with constant semi-variogram values at

variance?

all lag distances (Fig. 5.3) indicates a random distribution with no dominant spatial scale. Linear or curvilinear variogram increase in semi-variance with lag distance indicates trend (Fig. 5.4), having a period at least twice that of the longest lag. Dominant spatial scale (Fig. 5.5) is indicated by an increase in semi-variance to a constant value towards peak. The wavelength of the spatial scale is two times the lag distance at which semi-variance first reaches the sill or peak value.

In the present study, a fixed lag distance i.e. at the interval of every 5th pixel with coastal pixel as reference was considered for semi-variance calculation thus resulting in a model as follows:

Semi-Variance = $[g_x - g(x+h)]^2$

How ~~you~~ can you get the variogram if lag-dist is constant (5 pixels)?

where

gx = reference coastal pixel's DN value

g(x+h) = DN value of pixel after lag distance 'h'.

5.4 Preparation Of Remote Sensing Data Methodology

IRS-1B LISS-I geocoded four band data was procured from National Remote Sensing Agency (NRSA), hyderabad, in the form of computer compatible tapes (CCTs). CCTs along with scene negatives were used to cover the study area. Data was in the form of National Data Centres (NDC) original band interleaved by line (BIL) format. Fig. 5.6 shows the schematic representation of the methodology.

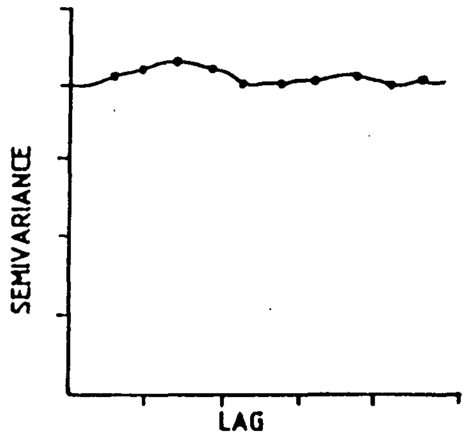


Fig. 5.3 VARIOGRAM INDICATING RANDOM DISTRIBUTION.

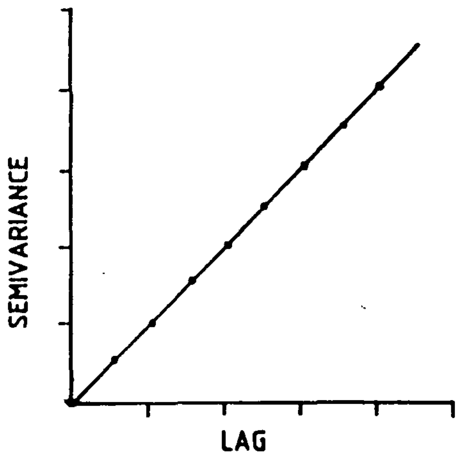


Fig. 5.4 VARIOGRAM INDICATING TREND.

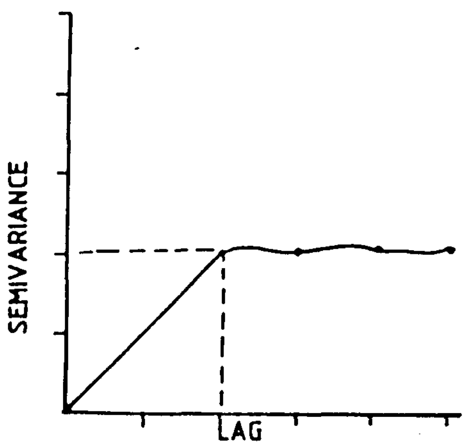


Fig. 5.5 VARIOGRAM INDICATING CONSTANT VALUE.

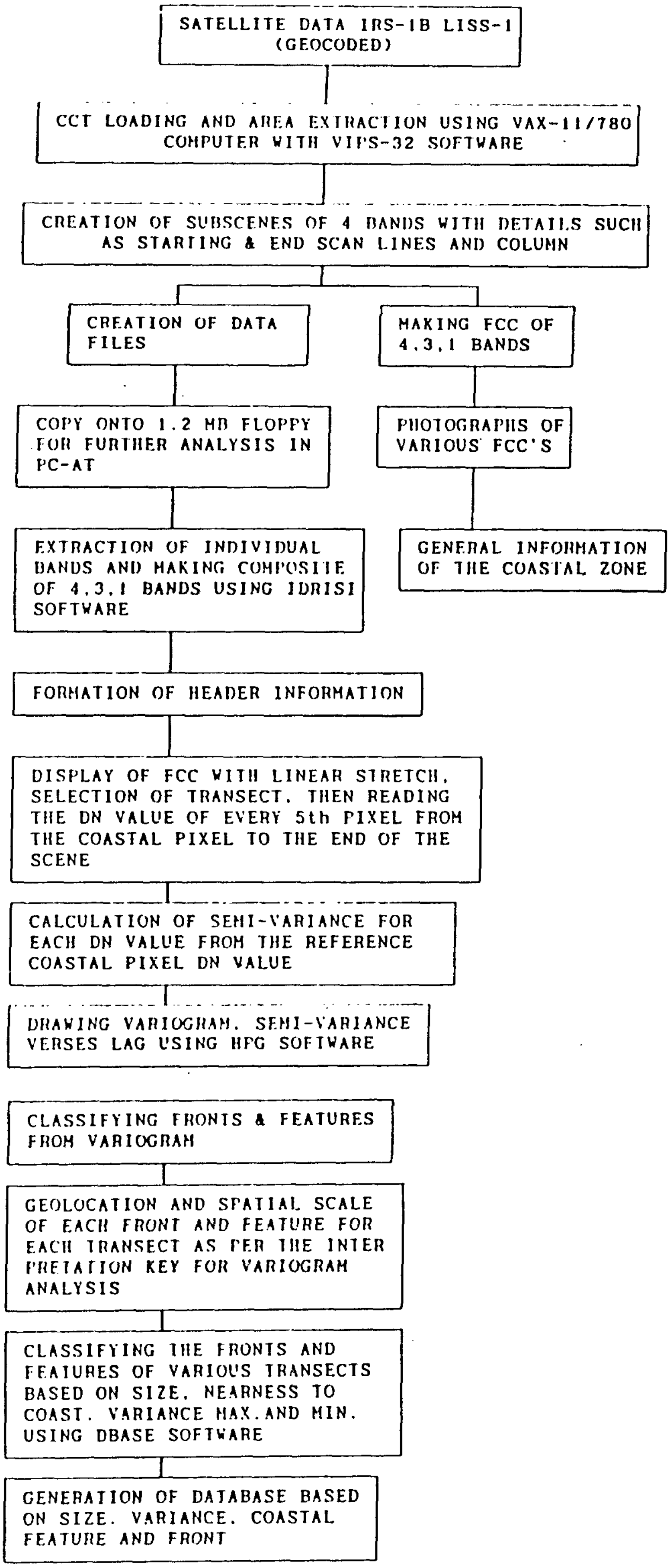


Fig. 5.6 Schematic representation of various steps involved in variogram analysis

5.5 Preparation Of Data For Variogram Analysis

All the three CCTs of three seasons were down-loaded into VAX11/780 computer for analysis through VIPS-32 software. Its header information was noted down as total number of scanlines and columns, number of bands, date of pass, latitude and longi tude of the scene centre, etc. Coastal areas of interest (Fig. 5.7) were identified and subscenes of 512x512 pixel window size were created. Starting and end scanline and column were recorded so as to locate the latitude and longitude of transects studied. False colour composites (FCCs) using bands 4,3,1 were made and photographed to derive the general information of the coastal zone. Subscene in all the four bands thus created were converted into data files and copied onto floppies, the seasonal data were averaged. These floppies containing subscene data were transferred to PC-AT for further analyses using IDRISI software. Software was used for individual band extraction and 4,3,1 band combination for making composite images. Header file was created for each composite image for further analysis in UNESCO's BILKO software.

False colour composite (FCC) image obtained by the conversion of subscene data files to image files by IDRISI software, were then loaded in BILKO software of UNESCO. BILKO is an image processing software which helps to read the digital value (DN value number) of any place inside image through its cursor option. Before noting down DN value, a standard format for

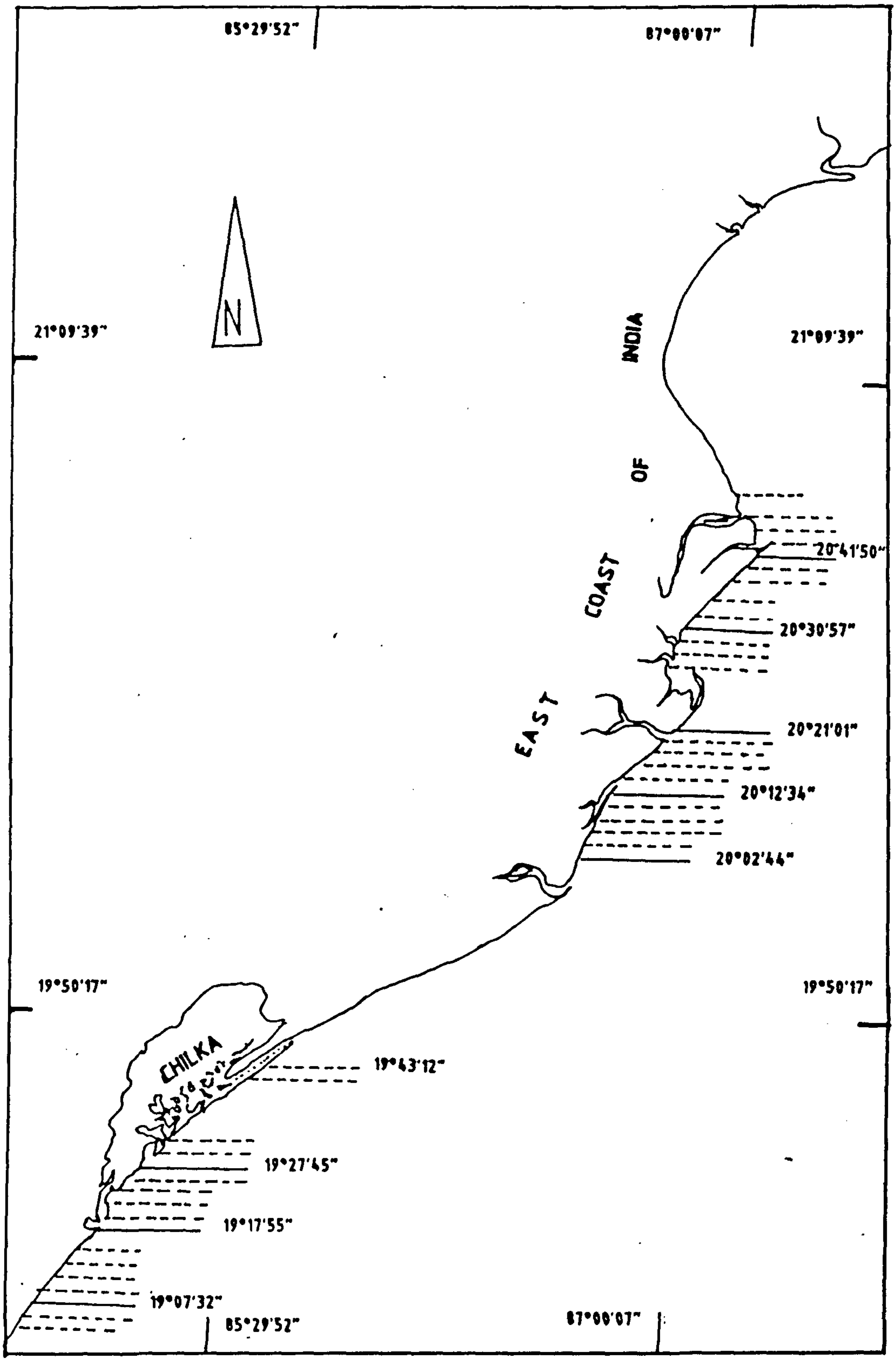


FIG. 5.7 COMPOSITE MAP OF ALL THE TRANSECTS MADE FOR STUDY AREA

variogram analysis was made. This format contained columns and lines to record various information like CCT number, latitude, coastal pixel column number, longitude, sampled pixel column and longitude, total number of points, total distance sampled, etc. DN value of every 5th pixel (i.e 72.5mx5 = lag) along with its number was noted with reference to coastal pixel. This was repeated for every transect selected for the study. Semi-variance was calculated as per the formula given earlier in this Chapter. Semi-variance values for all the transects thus obtained from variogram analysis were then sent to Harvard Graphics to draw variograms i.e. lag Vs semi-variance as shown in the next Chapter (Fig. 6.2-6.41).

features ≐ [illegible]
(The word seems to be general)

5.6 Deriving Spatial Scales

Fronts and features were identified from the output graphs or variograms. Fronts are the sharp boundaries between two water bodies seperated by sharp variance gradient, whereas features are not having greater variance difference. They indicate similarity in water bodies. Output of variograms were analysed to derive the spatial scale of fronts and features for each transect. An interpretation key was developed for variogram to obtain information as latitude, longitude, size, nearness to coast, variance difference for each feature and front for every variogram.

5.7 Classification Of Spatial Scales

Information gathered in the interpretation key for variogram was then analysed in database management mode. Each transect latitude was identified for various fronts and features present in it. Then each front/feature was seperately identified in terms of its geographic location in degrees, minutes and seconds. Each feature or front was traced seperately with it's beginning longitude and end longitude. Ascertaining beginning and end longitude position of features/fronts helped in exactly knowing the size of the feature/front. Then taking coastal pixel as reference pixel from where the scanning began, each features/fronts nearness to the coast was calculated. Difference in variance was noted as minimum variance and maximum variance for each of the front or feature. Sharper difference in variance shows a stronger front in the area. Tables 5.1-5.13 shows all the fronts and features and their classification based on variance for the north-west Bay of Bengal.

A common pattern was adopted for the classification of various parameters in the Tables 5.1 to 5.13. Classification of fronts based on variance are depicted in Tables 5.1 to 5.9 and of features in Tables 5.10 to 5.13. A difference of 50 was maintained in variance classification of all these tables in ascending order starting from Table 5.1 to 5.13.

Table 5.1 Classification of Fronts based on Variance <50 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2053.07	8705.47	8706.23	1.0875	10.0000	0	36
2051.10	8707.58	8708.34	1.0875	0.0000	0	36
2030.57	8654.48	8657.37	5.0750	0.0000	0	49
2028.57	8702.42	8702.54	0.3625	16.3125	0	36
2028.57	8705.55	8707.56	3.6250	22.1125	36	64
2014.35	8640.40	8641.16	2.9000	13.7750	36	49
2001.59	8546.24	8546.36	0.3625	0.0000	49	64
1959.58	8542.32	8542.47	0.3625	0.0000	64	81
1953.55	8529.07	8529.44	1.4500	0.0000	49	64
1941.12	8508.57	8515.23	11.9625	0.0000	64	100
1915.35	8442.41	8446.06	6.5250	0.0000	1	4
1913.34	8440.57	8442.22	2.9000	0.0000	49	64
1911.33	8439.03	8440.16	2.5375	0.0000	49	64
1909.33	8437.29	8439.42	4.3500	0.0000	49	64
1907.32	8435.57	8439.11	6.1625	0.0000	49	64
1905.31	8434.40	8435.16	1.4500	0.0000	49	64
1929.46	8455.20	8456.57	3.2625	0.0000	36	64
1927.45	8453.19	8454.44	2.9000	0.0000	36	64
1925.44	8451.23	8452.36	2.5375	0.0000	36	64
1919.56	8447.09	8447.33	1.0875	0.0000	0	49

Table 5.2 Classification of Fronts based on Variance >49 & <100 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2039.49	8720.06	8720.29	0.7250	29.0000	196	289
2037.48	8719.53	8720.06	0.3625	32.6250	196	289
2026.56	8706.46	8707.46	1.8125	19.2125	169	225
2024.55	8703.33	8705.33	3.6250	14.1375	144	225
2024.55	8709.59	8710.23	0.7250	25.7375	225	289
2004.45	8626.43	8630.57	7.6125	1.4500	1	64
2002.44	8630.47	8631.23	1.0875	10.5125	4	81
1957.57	8538.28	8541.17	5.4375	0.0000	1	100
1955.56	8533.31	8536.20	5.4375	0.0000	1	81
1951.16	8523.53	8524.42	1.8125	0.0000	4	100
1945.13	8515.04	8516.41	2.9000	1.8125	49	100
1943.12	8511.34	8517.36	11.2375	0.0000	49	121
1931.47	8457.09	8458.33	2.9000	0.0000	1	100
1921.57	8448.09	8448.34	1.0875	0.0000	0	64

Table 5.3 Classification of Fronts based on Variance >99 & <150 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2050.78	8704.32	8704.44	0.3625	3.2625	36	144
2057.08	8711.23	8713.36	3.9875	15.5875	324	441
2055.08	8706.04	8707.04	1.8125	2.9000	36	169
2053.07	8708.12	8708.24	0.3625	4.7125	36	144
2053.07	8711.50	8712.02	0.3625	11.2375	36	144
2051.10	8709.10	8709.22	0.3625	2.5375	36	144
2051.10	8711.59	8712.11	0.3625	7.6125	36	144
2043.51	8709.25	8711.25	3.6250	0.0000	0	144
2043.51	8720.17	8720.29	0.3625	19.9375	400	529
2041.50	8716.15	8717.04	1.4500	18.4875	49	196
2034.59	8707.29	8708.30	1.8125	16.3125	36	169
2032.58	8706.00	8706.12	0.3625	17.0375	36	144
2030.57	8704.16	8704.28	0.3625	17.4000	36	144
2026.56	8701.44	8701.56	0.3625	10.1500	36	144
2024.55	8700.43	8700.56	0.3625	9.0625	36	144
1947.14	8518.34	8519.23	1.4500	3.2625	0	100

Table 5.4 Classification of Fronts based on variance >149 & <200 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2057.08	8708.22	8708.34	0.3625	10.1500	144	324
2055.08	8710.54	8711.06	0.3625	11.6000	144	324
2055.08	8712.19	8712.31	0.3625	14.1375	144	324
2039.49	8711.13	8712.38	2.5375	13.0500	0	196
2037.48	8709.25	8711.13	3.2625	13.7750	0	169
2010.33	8640.59	8641.47	1.4500	21.3875	100	256
2008.32	8635.28	8635.52	0.7250	12.6875	64	256
2006.31	8633.37	8633.49	0.3625	10.8750	36	225
1917.55	8445.35	8448.00	4.7125	0.0000	36	225

Table 5.5 Classification of Fronts based on Variance >199 & <250 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2055.08	8713.43	8714.07	0.7250	16.6750	144	361
2019.00	8648.50	8652.39	6.8875	14.1375	49	256
2016.59	8649.28	8653.42	7.6125	15.5875	49	289
2012.34	8635.50	8647.06	20.3000	9.0625	36	256
1949.15	8520.23	8521.36	2.5375	0.0000	36	256

Table 5.6 Classification of Fronts based on Variance >249 & <300 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2017.38	8647.16	8654.19	12.6875	11.9625	36	289
2021.01	8649.24	8652.37	5.8000	10.8750	1	289

Table 5.7 Classification of Fronts based on Variance >299 & <350 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2041.50	8720.17	8720.41	0.7250	25.7375	196	529

Table 5.8 Classification of Fronts based on Variance >399 & <450 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2045.52	8717.38	8718.50	2.1750	11.2375	36	484
2043.51	8715.39	8718.53	5.8000	11.6000	36	484

Table 5.9 Classification of Fronts based on Variance >449 & <500 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2047.53	8718.02	8719.14	2.1750	7.6125	36	529

Table 5.10 Classification of Features based on Variance <50 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2057.08	8702.56	8704.32	2.9000	0.0000	0	36
2057.08	8704.44	8708.22	6.5250	3.6250	144	144
2057.08	8708.34	8711.23	5.0750	10.5125	324	324
2057.08	8713.36	8715.01	2.9000	19.5750	441	441
2055.08	8704.39	8706.04	2.5375	0.0000	0	36
2055.08	8707.04	8710.54	6.8875	4.7125	144	144
2055.08	8711.06	8712.19	2.1750	11.9625	324	324
2055.08	8712.31	8713.43	2.1750	14.5000	144	144
2055.08	8714.07	8715.20	2.1750	17.4000	361	361
2053.07	8706.23	8708.12	3.2625	1.4500	36	36
2053.07	8708.24	8711.50	6.1625	5.0750	144	144
2053.07	8712.02	8712.38	1.0875	11.6000	36	36
2051.10	8708.34	8709.10	1.0875	1.4500	36	36
2051.10	8709.22	8711.59	4.7125	2.9000	144	144
2051.10	8712.11	8715.13	5.4375	7.9750	36	49
2047.53	8714.00	8718.02	7.2500	0.0000	0	36
2045.52	8711.35	8717.38	10.8750	0.0000	0	36
2045.51	8711.25	8715.39	7.6125	3.9875	0	36
2041.50	8706.11	8716.15	18.1250	0.0000	0	49
2041.50	8717.04	8720.17	5.8000	19.9375	196	196
2041.50	2720.41	8722.06	2.5375	26.4625	529	529
2039.49	8704.10	8711.13	12.6875	0.0000	0	36
2039.49	8712.38	8720.06	13.4125	15.5875	169	196
2039.49	8720.29	8722.06	2.9000	29.7250	289	289
2037.48	8701.58	8709.25	13.4125	0.0000	0	0
2037.48	8720.06	8722.06	3.6250	32.9875	289	289
2034.59	8658.38	8707.29	15.9500	0.0000	0	36
2034.59	8708.30	8711.43	5.8000	18.1250	169	196
2032.58	8656.44	8706.00	16.6750	0.0000	0	36
2030.57	8657.37	8704.16	11.9625	5.4375	0	36
2028.57	8653.50	8702.42	15.9500	0.0000	0	1
2028.57	8702.54	8705.55	5.4375	16.6750	36	36
2028.57	8707.56	8711.46	6.8875	25.7375	64	81
2026.56	8656.18	8701.44	9.7875	0.0000	0	36
2026.56	8701.56	8706.46	8.7000	10.5125	144	169
2026.56	8707.46	8711.36	6.8875	21.0250	196	225
2024.55	8656.06	8700.43	8.3375	0.0000	0	36
2024.55	8700.56	8703.33	4.7125	9.4250	144	144
2024.55	8705.33	8709.59	7.9750	17.7625	196	225
2024.55	8710.23	8711.48	2.5375	26.4625	289	289
2004.45	8626.07	8626.43	1.4500	0.0000	0	1
2004.45	8630.57	8641.37	19.2125	9.0625	64	81
2002.44	8625.09	8630.47	10.5125	0.0000	0	4
2002.44	8631.23	8634.25	5.4375	11.6000	81	81
2017.38	8641.38	8647.16	11.9625	0.0000	0	36
2017.38	8654.19	8656.56	4.7125	12.6875	289	289

Contd....

Tablo 5.10 Classification of Features based on Variance <50 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2021.01	8643.33	8649.24	10.8750	0.0000	0	1
2021.01	8652.37	8653.49	2.1750	16.6750	256	289
2019.00	8641.11	8648.50	14.1375	0.0000	0	49
2019.00	8652.39	8653.52	2.1750	21.0250	256	256
2016.59	8641.01	8649.28	15.5875	0.0000	0	49
2014.35	8633.12	8640.40	13.7750	0.0000	0	36
2014.35	8641.16	8647.06	8.7000	17.0375	36	49
2012.34	8631.00	8635.50	9.0625	0.0000	0	49
2006.31	8627.46	8633.37	10.8750	0.0000	0	36
2006.31	8633.49	8647.06	23.9350	11.2375	225	225
2001.59	8546.36	8548.25	3.6250	0.7250	64	81
1957.57	8541.17	8548.20	13.0500	5.4375	100	81
1955.56	8536.20	8548.25	22.1125	5.4375	81	100
1953.55	8529.44	8548.15	33.7125	1.4500	81	100
1951.16	8524.42	8528.31	7.2500	1.8125	100	100
1949.15	8521.36	8528.38	13.0500	2.5375	225	256
1954.13	8515.16	8515.04	1.8125	0.0000	1	49
1945.13	8516.41	8528.34	21.3875	4.7125	100	121
1943.12	8517.36	8528.41	19.9375	11.2375	100	121
1941.12	8515.23	8528.41	23.9250	11.9625	81	100
1915.35	8446.06	8453.09	12.6875	6.5250	4	9
1913.34	8442.22	8453.14	19.5750	2.9000	64	81
1911.33	8440.16	8453.09	23.2000	2.5375	64	81
1909.33	8439.42	8453.12	24.2875	4.3500	64	81
1907.32	8439.11	8453.16	25.3750	6.1625	64	81
1905.31	8435.16	8453.12	32.2625	1.4500	49	81
1931.47	8458.33	8511.27	23.2000	2.9000	81	121
1929.46	8456.57	8511.27	26.1000	3.2625	64	100
1927.45	8454.44	8511.27	30.0875	2.9000	64	100
1925.44	8452.36	8511.31	34.0750	2.5375	64	100
1921.57	8448.34	8505.41	30.8125	1.0875	64	100

Table 5.11 Classification of Features based on Variance >49 & <100 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2037.48	8711.13	8719.53	15.5875	17.0375	144	196
2032.58	8706.12	8711.50	10.1500	17.4000	144	225
2030.57	8704.28	8711.43	13.0500	17.7625	144	225
2010.33	8641.47	8647.13	9.7875	22.8375	196	256
2008.32	8628.37	8635.28	12.6875	0.0000	0	64
2008.32	8635.52	8647.09	20.3000	13.4125	196	256
1917.55	8448.00	8505.43	31.9000	4.7125	225	289

Table 5.12 Classification of Features based on Variance >99 & <150 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
2047.53	8719.14	8722.03	5.0750	9.7875	400	529
2045.52	8718.50	8722.03	5.8000	13.4125	400	529
2010.33	8629.18	8640.59	21.3875	0.0000	0	100

Table 5.13 Classification of Features based on Variance >199 & <250 in North west Bay of Bengal

LATITUDE	BEGINNING LONGITUDE	END LONGITUDE	SIZE IN Km	NEARNESS TO COAST	MINIMUM VARIANCE	MAXIMUM VARIANCE
1919.56	8447.33	8505.41	32.6250	1.0875	49	289

Maximum number of fronts were observed in Table 5.1 which had a variance less than 50, signifying weaker fronts. The fronts generally tend to decrease in number in higher variance values. It was observed that fronts as well as features both tend to decrease in numbers with ascending variance values i.e. from less than 50 to less than 500. A sharper difference in minimum and maximum variance values is representative of a stronger front. The sharper and stronger fronts/features thus calculated through this analysis is of great help in locating the presence of various fish species. Frontal maps can be effe ciently produced from spatial scale analysis of fronts/features for assessing fishery resources in the ocean.

CHAPTER SIX

RESULTS AND DISCUSSION

6.0 TARGETTING FISH RESOURCE POTENTIAL: A DISCUSSION

Our ultimate target of this study was to conduct some studies on coastal zone fishery resource potential. It has been able to complete this study very successfully with the help of remote sensing and geographical information system techniques. A resource information database has been generated by the comparison of fish catch data derived images and the satellite derived variograms. Schematic sketch (Fig. 6.1) explains the outcome of the work to some extent.

Fig. 6.1 clearly explains that it has been possible to acheive our goals by gaining in three ways. Firstly, a technology for identifying fronts and features as instable and stable processes respectively has been developed. Earlier it has been done with wide field of view (WiFS) sensors in large expanses of oceans, but here it has been done on smaller areas of coastal zones using Indian Remote Sensing Satellite data.

Secondly, it has been able to obtain and interface the time space series of ground truth data by performing independent variogram analysis on it.

Thirdly, fish image data was properly interfaced with satellite variograms and its composite results showed some dependance of resources on the processes.

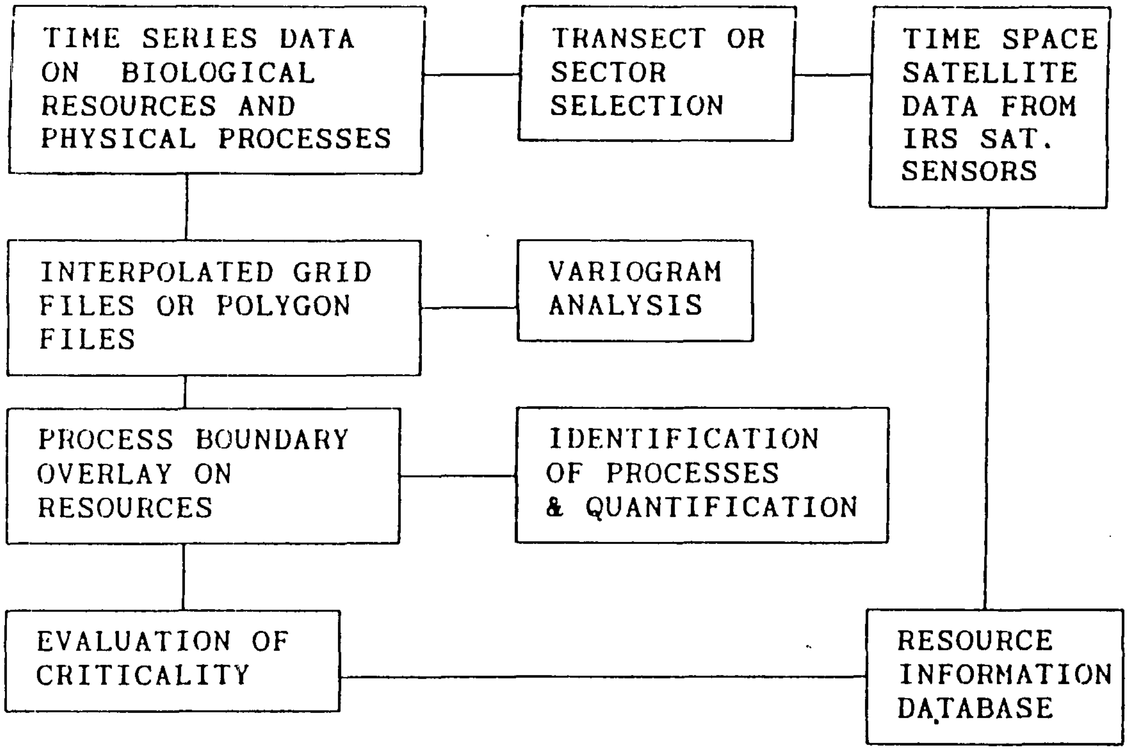


Fig. 6.1 Schematic sketch of the outcome as anticipated in the present study.

Table 6.1 Categorization of fishes based on their distribution and availability.

S.NO.	ZONE	POSITION	FISHES
1	Very Scarce	Patchy	Skate
2	Scarce	Patchy	Eel, Seabream, Psenus
3	Unizonal	18^{O}-$19^{O}45'$N & 84^{O}- $86^{O}30'$E	Barracuda, Chorinemus, Seer fish, Silverbelly
4	Bizonal	(i) 18^{O}-$19^{O}30'$N & 84^{O}-$85^{O}30'$E (ii) 20^{O}-$20^{O}40'$N & $86^{O}45'$-$88^{O}20'$E	Decapterids, Priacanthus
5	Qudrizonal	(i) 18^{O}-$18^{O}30'$N & 84^{O}-$84^{O}30'$E (ii) 19^{O}-$19^{O}30'$N & $84^{O}50'$-$85^{O}30'$E (iii) $19^{O}25'$-$19^{O}45'$ N & $85^{O}50'$-$86^{O}30'$E (iv) $19^{O}50'$-$20^{O}45'$ N & $86^{O}45'$-$87^{O}40'$E	Shark Dhoma Clupeids Leognathids Chirocentrus
6	Well Distributed	18^{O}-21^{O}N & 84^{O}-$88^{O}30'$E	Ribbon fish, Cuttle fish, Caranx, Lizard fish, Prawn, Flatfish, Rays
7	Very Well Distributed	18^{O}-21^{O}N & 84^{O}-$88^{O}30'$E	Upenoids, Karkara, Squid, Nemipterids, Mackerel, Catfish, Pomfret

Ultimately interfacing of all these have yielded a rich resource information database, showing the areas of strong frontal zones, size of the fronts/features, its minimum and maximum variance range, etc. The results of this exhaustive study are discussed below as follows:

Fish resources data in the form of interpolated grid files were overlayed over each other and then grouped into following seven different categories based on their distribution and availability in the region (Table 6.1).

1. Very Scarce
2. Scarce
3. Unizonal
4. Bizonal
5. Quadrizonal
6. Well Distributed
7. Very Well Distributed

These categories had a combination of fish species which shared almost common areas or habitats. These areas were checked and compared with the availability of any front or feature (derived from the satellite data) present in it. Here a front is the entity which is instable spatially, that which shows a sharp change in semi-variance against the unit distance and that which performs a transition between stable entities , whereas, feature is anti-thesis to front.

The results presented as variograms (the outcome of umpteem number of transects satellite data shown in the plates earlier in Chapter 3. All these variograms show composite radiance of IRS-1B, LISS-1 data.

How is it defined ?

The information of variogram analysis is variously classi fied and is presented in individual Tables. While referring to data it is suggested that very minute and erratic changes be ignored as they might be possibly due to data errors such as striping. It is ideal to appreciate the general trend of variograms rather than trying to explain each individual observation.

The fish resources data in the form of twenty-nine interpo lated grid files or image files (presented in Chapter 4) were compared with variograms of the region to observe presence of any fronts or features in its seven categories. The results were classified in terms of size, nearness to coast and amount of variance within their spread.

It was observed that fronts (based on size) between 0.3625-5km were numerous, more than 10km in size were a few and more than 20km size were rare.

For features also (based on size), it was observed that the

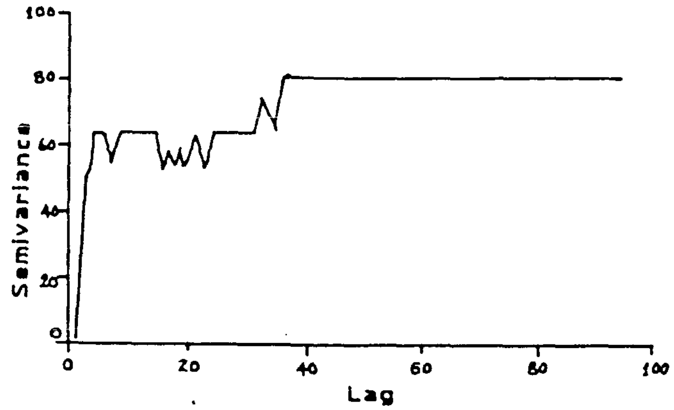


Fig. 6.2 VARIOGRAM OF TRANSECT 19°05'31"

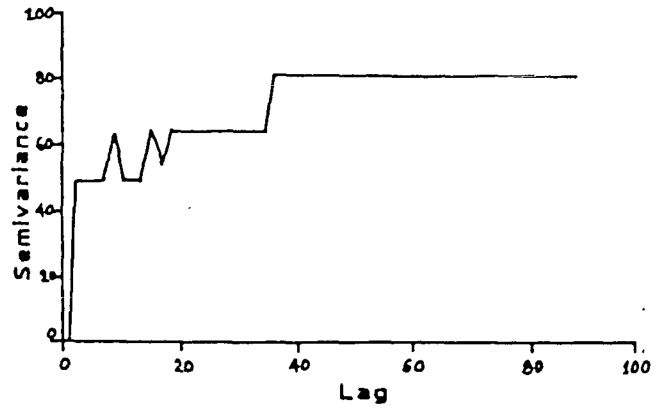


Fig. 6.3 VARIOGRAM OF TRANSECT 19°07'32"

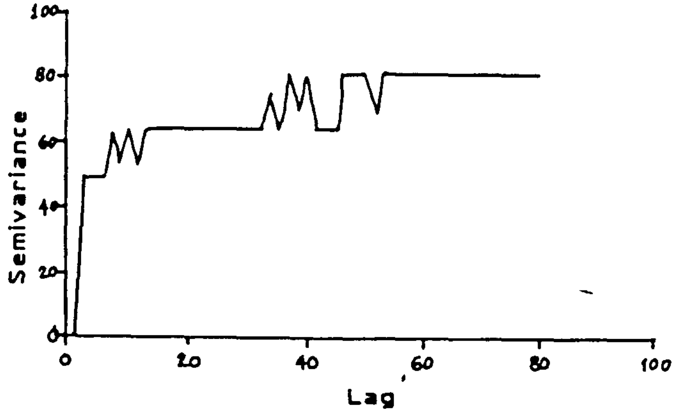


Fig. 6.4 VARIOGRAM OF TRANSECT 19°09'33"

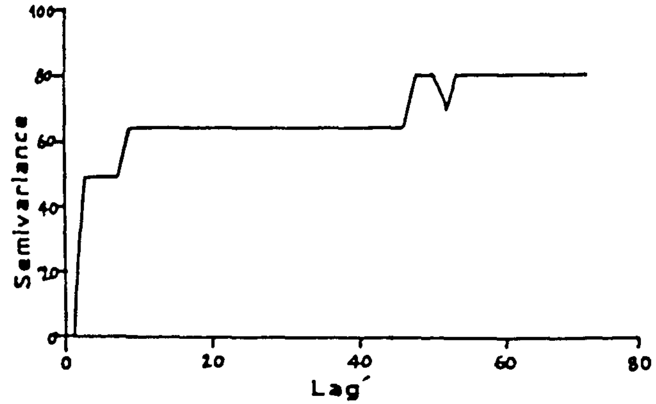


Fig. 6.5 VARIOGRAM OF TRANSECT 19°11'33"

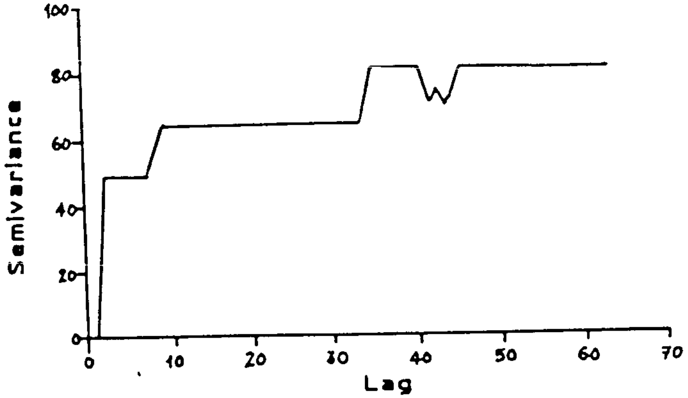


Fig. 6.6 VARIOGRAM OF TRANSECT 19°13'34"

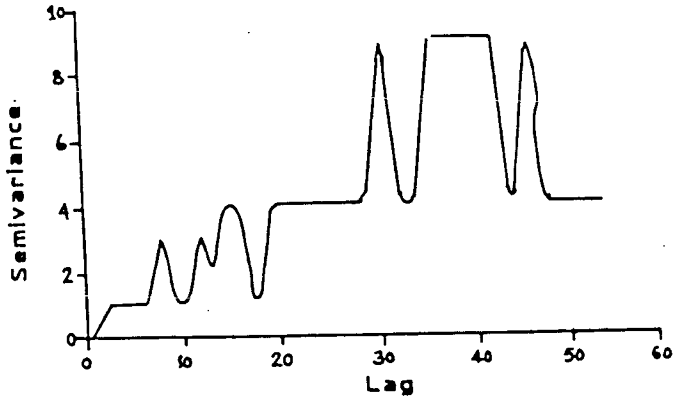


Fig. 6.7 VARIOGRAM OF TRANSECT 19°15'35"

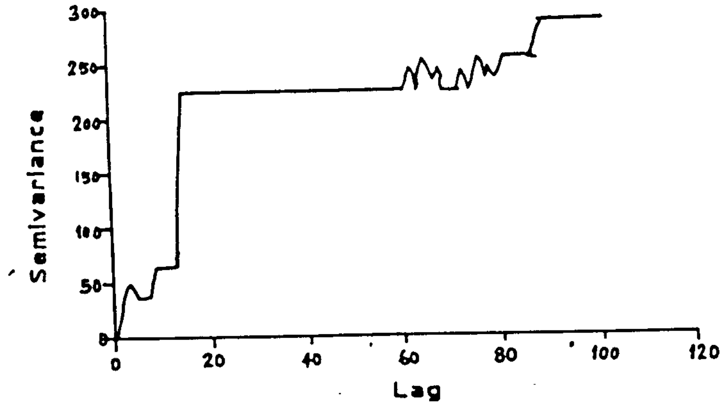


Fig. 6.8 VARIOGRAM OF TRANSECT 19°17'55"

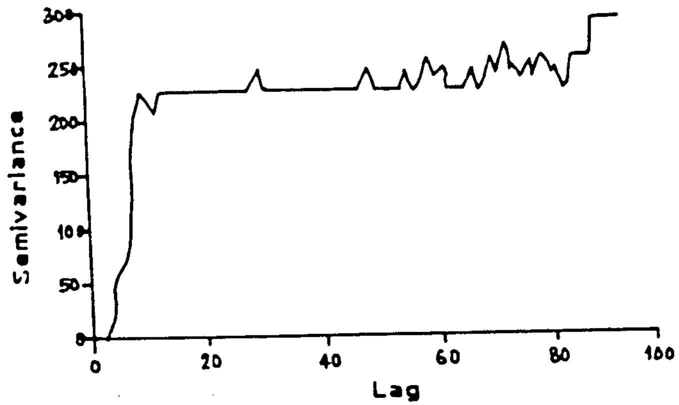


Fig. 6.9 VARIOGRAM OF TRANSECT 19°19'56"

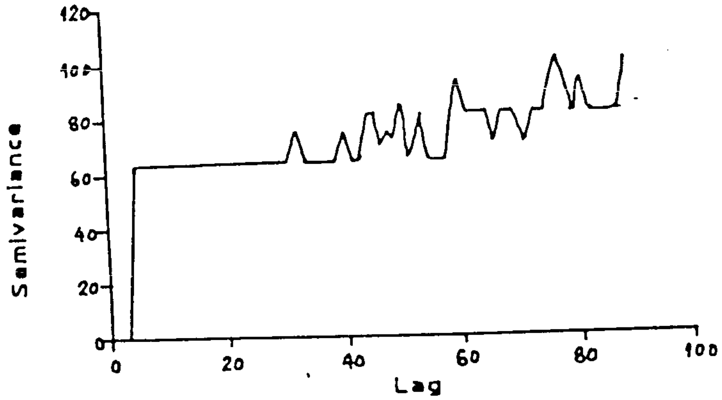


Fig. 6.10 VARIOGRAM OF TRANSECT 19°21'57"

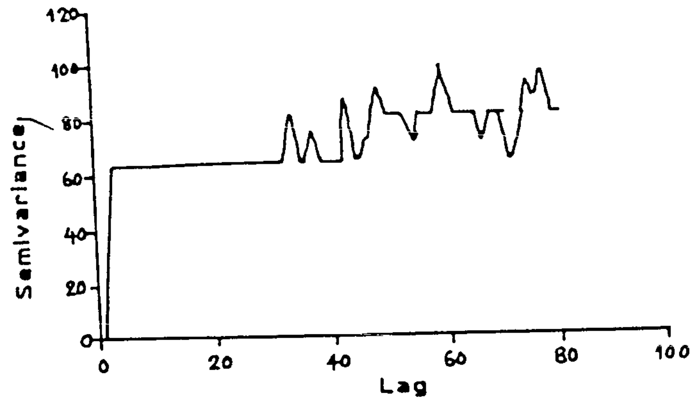


Fig. 6.11 VARIOGRAM OF TRANSECT 19°23'58"

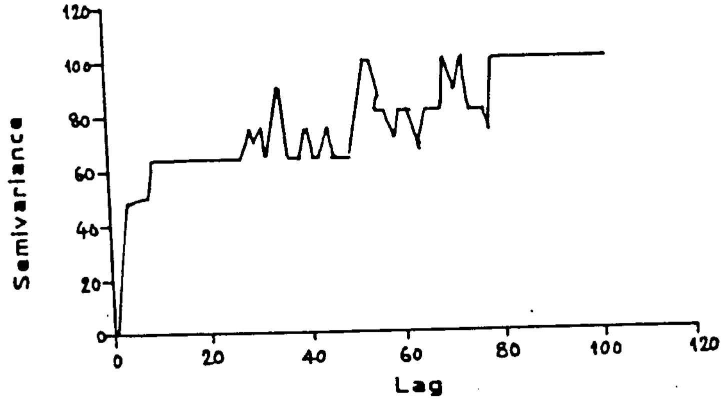


Fig. 6.12 VARIOGRAM OF TRANSECT 19°25'44"

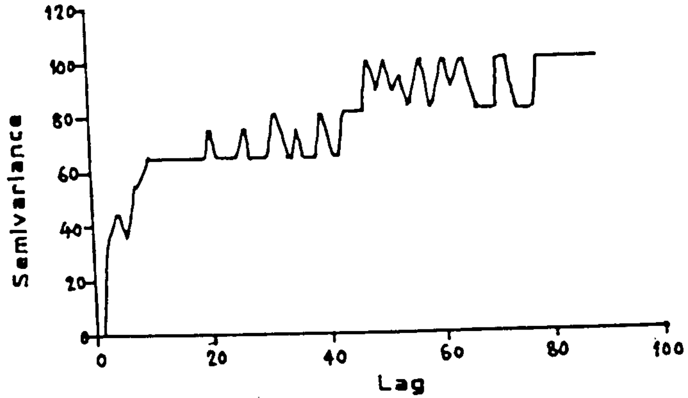


Fig. 6.13 VARIOGRAM OF TRANSECT 19°27'45"

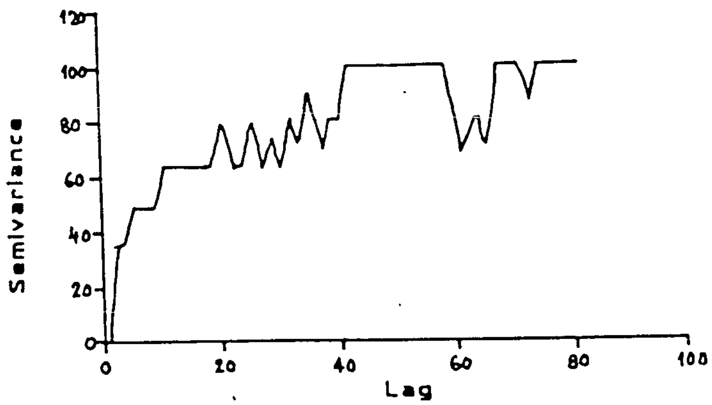


Fig. 6.14 VARIOGRAM OF TRANSECT 19°29'46"

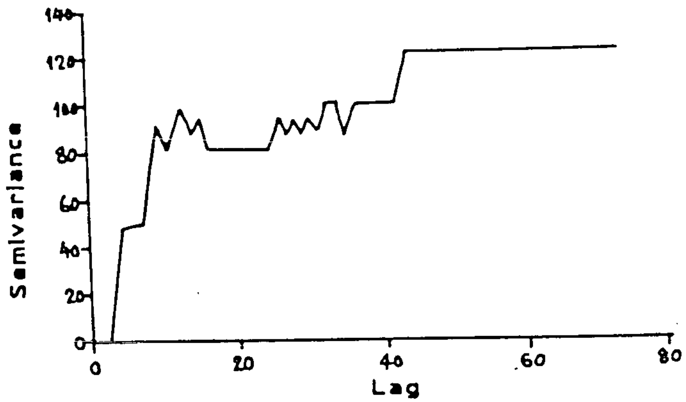


Fig. 6.15 VARIOGRAM OF TRANSECT 19°31'47"

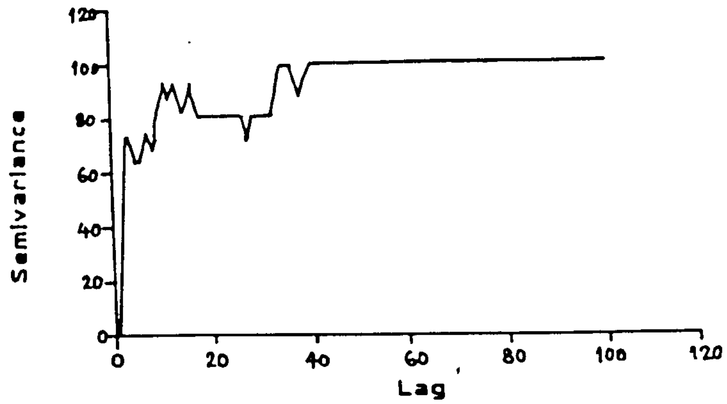


Fig. 6.16 VARIOGRAM OF TRANSECT 19°41'12"

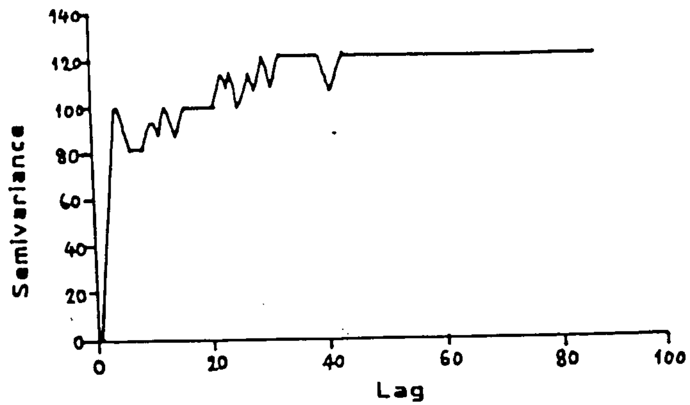


Fig. 6.17 VARIOGRAM OF TRANSECT 19°43'12"

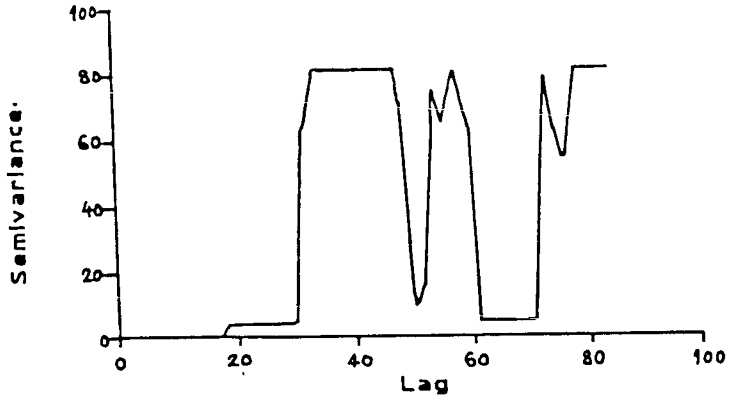


Fig. 6.18 VARIOGRAM OF TRANSECT 20°02'44"

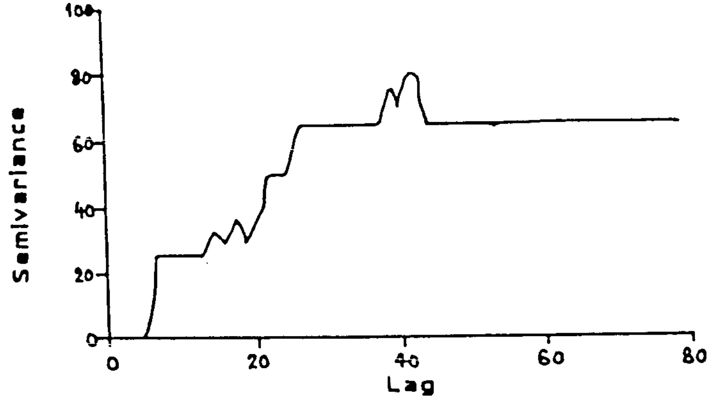


Fig. 6.19 VARIOGRAM OF TRANSECT 20°04'45"

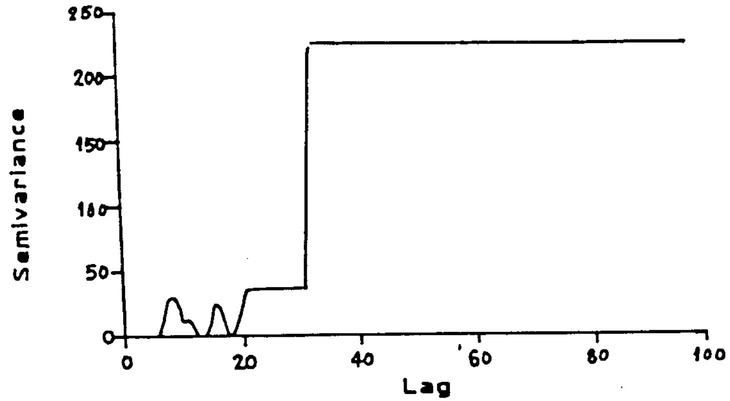


Fig. 6.20 VARIOGRAM OF TRANSECT 20°06'31"

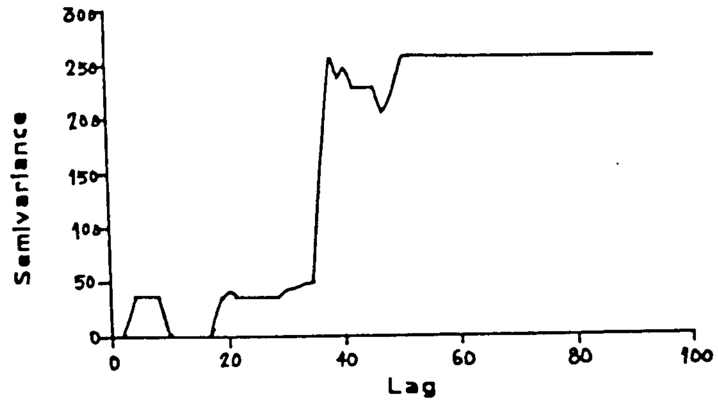


Fig. 6.21 VARIOGRAM OF TRANSECT 20°08'32"

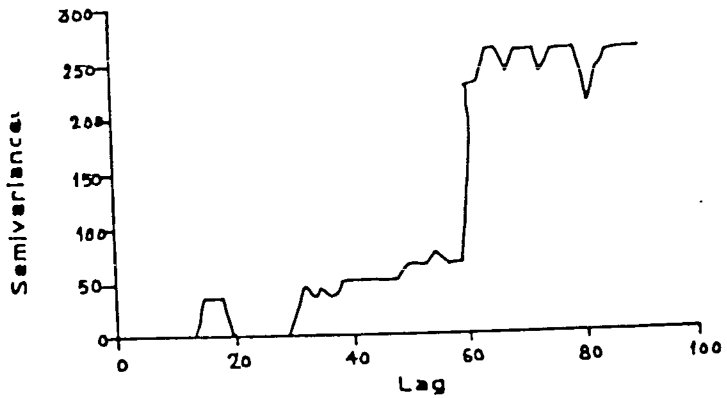


Fig. 6.22 VARIOGRAM OF TRANSECT 20°10'33"

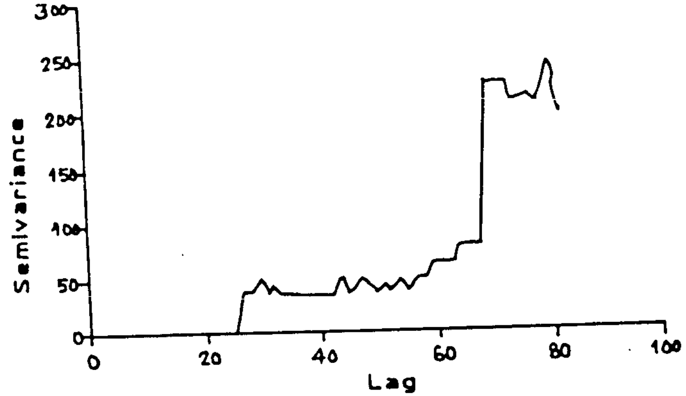


Fig. 6.23 VARIOGRAM OF TRANSECT 20°12'34"

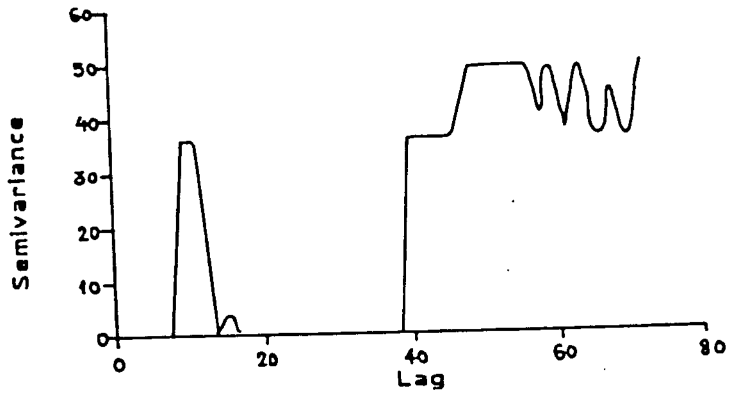


Fig. 6.24 VARIOGRAM OF TRANSECT 20°14'35"

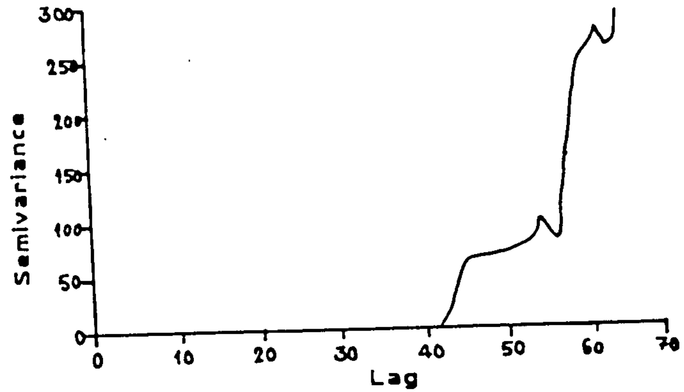


Fig. 6.25 VARIOGRAM OF TRANSECT 20°16'59"

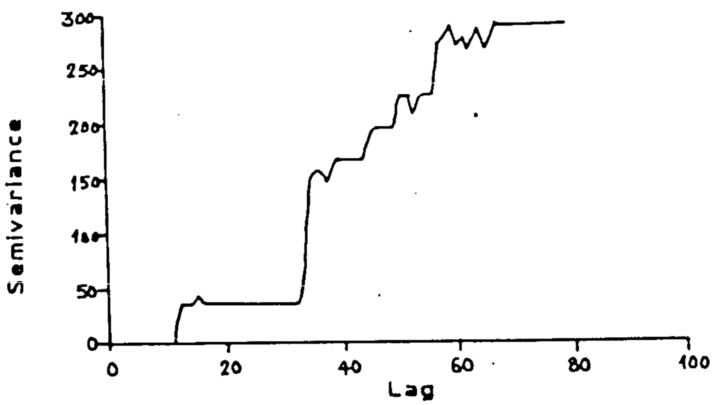


Fig. 6.26 VARIOGRAM OF TRANSECT 20°17'38"

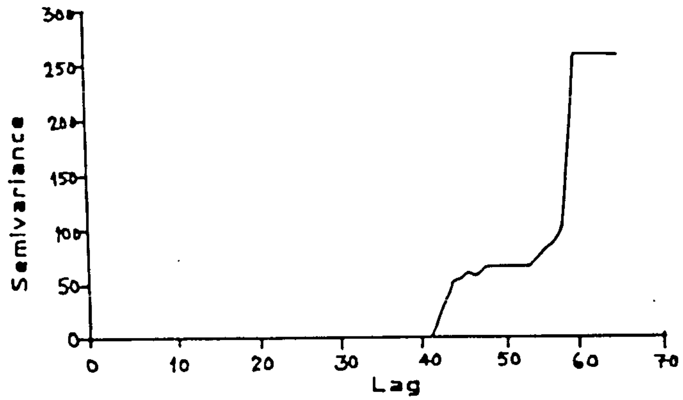
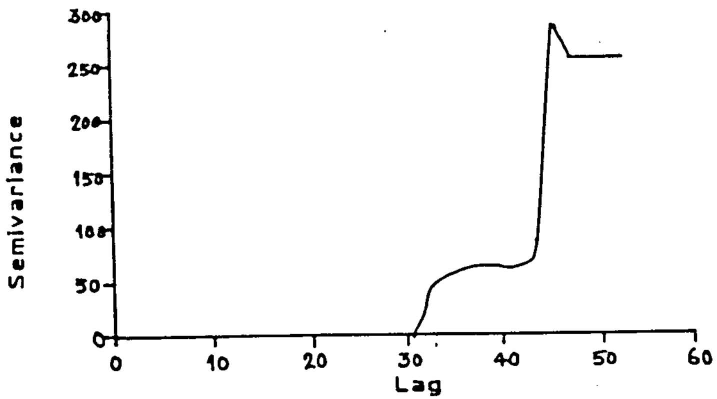


Fig. 6.27 VARIOGRAM OF TRANSECT 20°19'00"



rig. 6.28 VARIOGRAM OF TRANSECT 20°21'01"

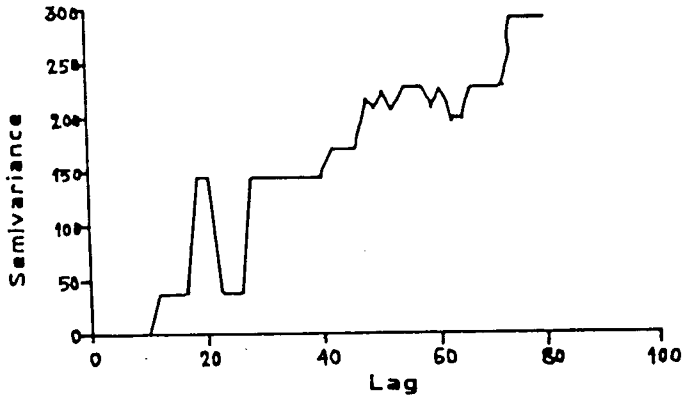


fig. 6.29 VARIOGRAM OF TRANSECT20°24'55"

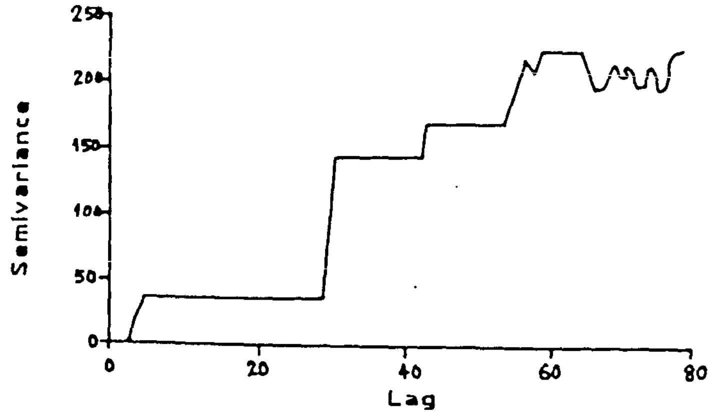


Fig. 6.30 VARIOGRAM OF TRANSECT 20°26'56"

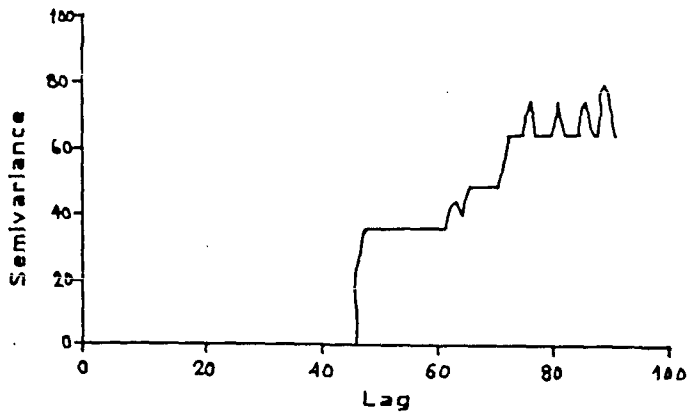


Fig. 6.31 VARIOGRAM OF TRANSECT 20°28'57"

Fig. 6.32VARIOGRAM OF TRANSECT 20°30'57"

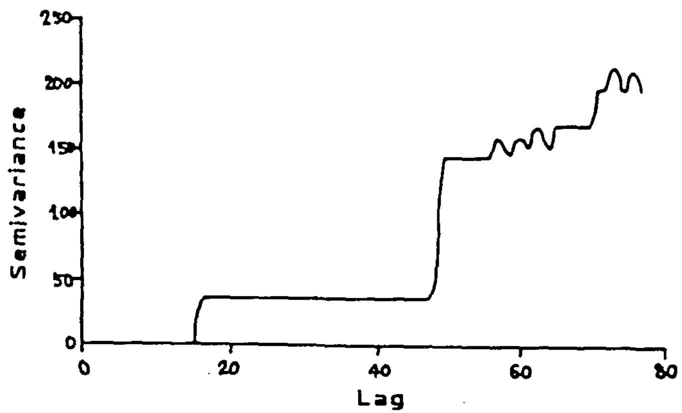


Fig. 6.33 VARIOGRAM OF TRANSECT 20°32'58"

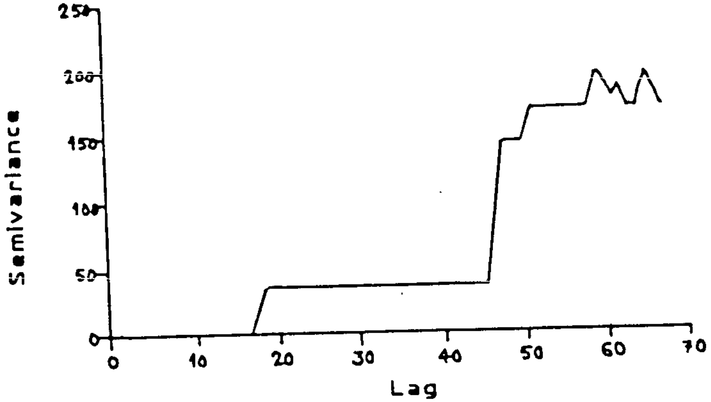


Fig. 6.34 VARIOGRAM OF TRANSECT 20°34'59"

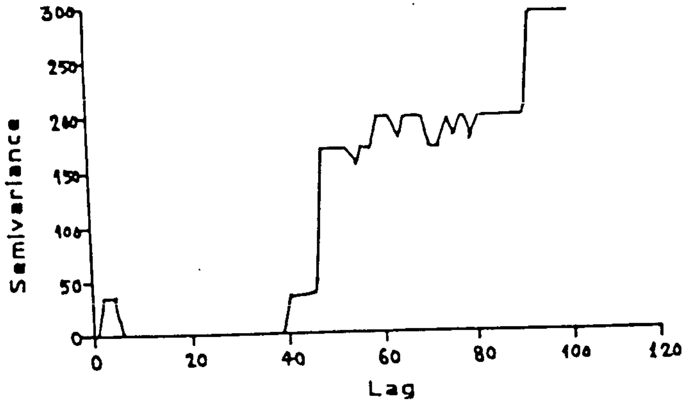


Fig. 6.35 VARIOGRAM OF TRANSECT 20°37'48"

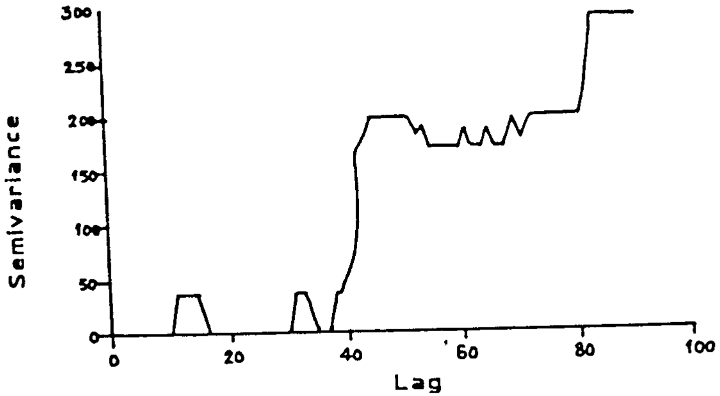


Fig.. 6.36 VARIOGRAM OF TRANSECT 20°39'49"

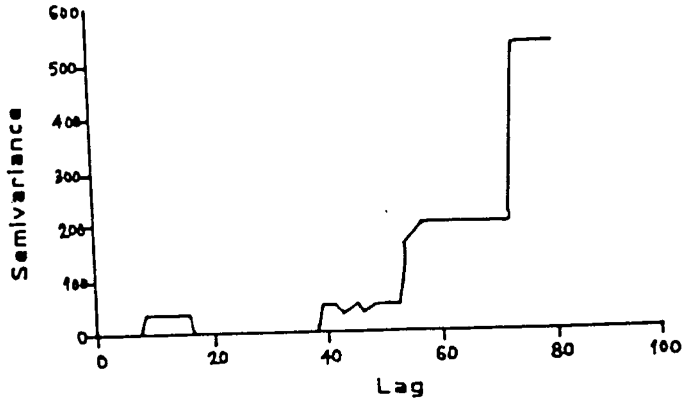


Fig. 6.37 VARIOGRAM OF TRANSECT 20°41'50"

Fig. 6.38 VARIOGRAM OF TRANSECT 20°43'51"

Fig. 6.39 VARIOGRAM OF TRANSECT 20°45'52"

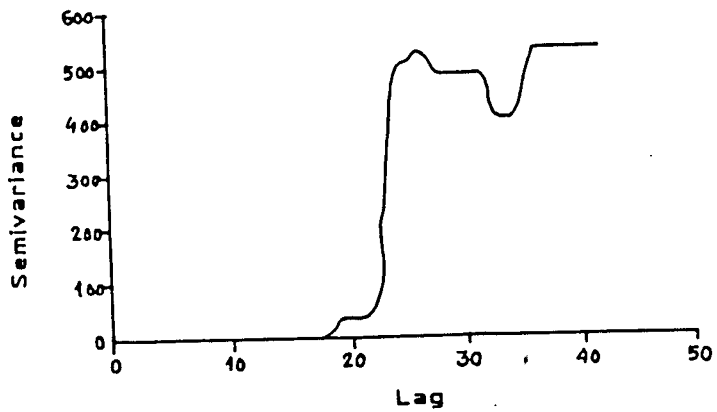


Fig. 6.40 VARIOGRAM OF TRANSECT 20°47'53"

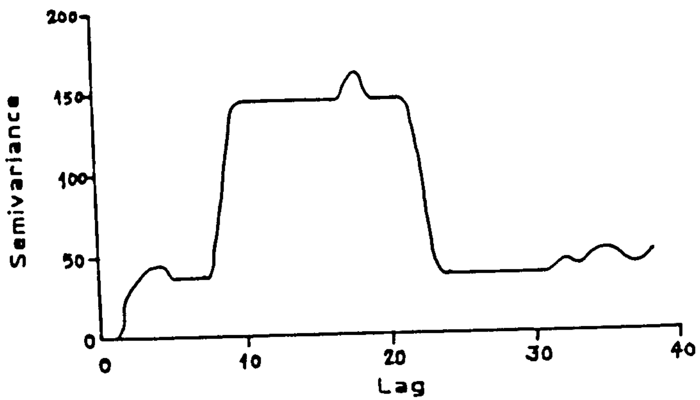


Fig. 6.41 VARIOGRAM OF TRANSECT 20°51'10"

feature size for a few ranged between 0.3625-5km and 5-10km. Majority were more than of 10km size i.e between 10km and 20km and also a considerable number were of size more than 30km.

The presence of a clear-cut front in the fish zone helped in establishing compatibility and relationship between oceanic features and fish presence. Category/zone-wise results are presented below:

6.1 Zone-wise Classification Of Fishes

6.1.1 VERY SCARCE

The category marked very scarce was a zone lying between 18°-18°30′ N and 84°-84°30′ E (Z1) and 20°15′-20°45′ N and 87°-87°30′ E (Z2). The fishes falling under this zone were the skate fishes. Patchy occurrence of skates was representative of it's localised presence. It's localised presence can be attributed to the favourable habitat or particular feeding ground present there which was favourable for the skates. A number of fronts were observed in zone Z2 when compared with the variograms of the same region.

6.1.2 SCARCE

This category was a zone with various types of fish resources distributed in patches. Various patches with fish resource data as observed in it lies in the areas between 18°-

18°20′ N and 84°-84°25′ E (Z1); 19°15′-19°30′ N and 85°-85°30′ E (Z2); 19°15′-19°35′ N and 86°-86°20′ E (Z3); and 20°-20°20′ N and 86°50′-87°10′ E (Z4). The fishes falling under this category were eels, sea breams and psenus. A number of fronts were observed in Zones Z2 and Z4 for eel fishes and psenus fishes. Though a patchy fish presence was also observed near zone Z2.

6.1.3 UNIZONAL

This category was a zone which lies in area between 18°-19° 45′ N and 84°-86°30′ E. The fishes found in this zone were barracudas, chorinemus, seer fishes and silver bellies. Almost all the fishes were observed in frontal areas with seer fishes occurring in strong front zone (20°-20°30′ N and 86°45′-87°15′ E).

6.1.4 BIZONAL

This category has two zones where fish aggregation was found. These zonal areas lies between 18°-19°30′ N and 84°-85° 30′E (Z1) and 20°-20°30′N and 86°45′-88°30" E (Z2). The fishes found in this category were priacanthus and decapterids. Both these fishes were observed in frontal zone areas Z1 and Z2.

6.1.5 QUADRIZONAL

This category has dense distribution of fishes in four marked zones. These four zones were areas lying between 18°-18° 30′ N and 84°-84°30′E (Z1); 19°-19°30′ N and 84°50′- 85°30′E (Z2); 19°25′-19°45′N and 85°50′-86°30′E (Z3) and 19°50′-20°45′N and

86°45'-87°40' E (Z4). The fishes found in this category were sharks, dhomas, clupeids, leognathids and chirocentrus. Zones Z2 and Z4 had a good number of fronts tallying with a good aggregation of fishes.

6.1.6 WELL DISTRIBUTED

This category covered almost the entire study area lying between 18°-21° N and 84°-88°30'E. The area had a fair distribution of ribbon fishes, cuttle fishes, carangids, lizard fishes, prawns, flat fishes and rays. Fish presence was certainly more prominent near the frontal zones found between 19°-20° N and 84°30'-85°45' E and 19°45'-21° N and 86°30'- 87°30'E.

6.1.7 VERY WELL DISTRIBUTED

This category also covered almost the entire study area i.e. area between 18°-21° N and 84°-88°30' E. The fishes found very well distributed in the entire study area were upe noids, karkaras, squids, nemipterids, mackerels, catfishes and pomfrets. Frontal zones found between 19°-20° N and 84°30'-85°45'E and 19°45'-21° N and 86°30'-87°30'E had good aggregation of fishes near or in them.

6.2 Frontal Map And Explanation

Nearly forty transects of different latitudes of the study area were extracted from the satellite data for studies. Vario grams were drawn for every transect. The transect was starting from the coast extending towards the sea till the end of the satellite data. Variogram analysis yielded a wealth of informa tion about the features and fronts observed in the area.

The fronts obtained from variogram analysis were classified into three categories based on their semi-variance range. These categories were:

i. Strong Fronts
ii. Medium Fronts
iii. Weak Fronts.

6.2.1 STRONG FRONTS

The category of strong fronts had semi-variance range be tween >200 and <500. The minimum variance was observed as 0 and maximum variance was seen as 529. The size of fronts ranged from 0.7250km to 20.3000km. Nearness to coast varied from 0 to 25.7375km. A front map was made from the classification of fronts for strong fronts (S) as shown in Fig. 6.42. Map shows patches of strong front zones marked as S in area between 20°-21° N and 86°30'-87°30'E.

6.2.2 MEDIUM FRONTS

The category of medium fronts had those fronts whose semi-variance ranged between >100 and <200. The minimum variance observed was 0 and maximum variance seen was 529. The size of fronts ranged from 0.3625km to 6.5250km. Nearness to coast

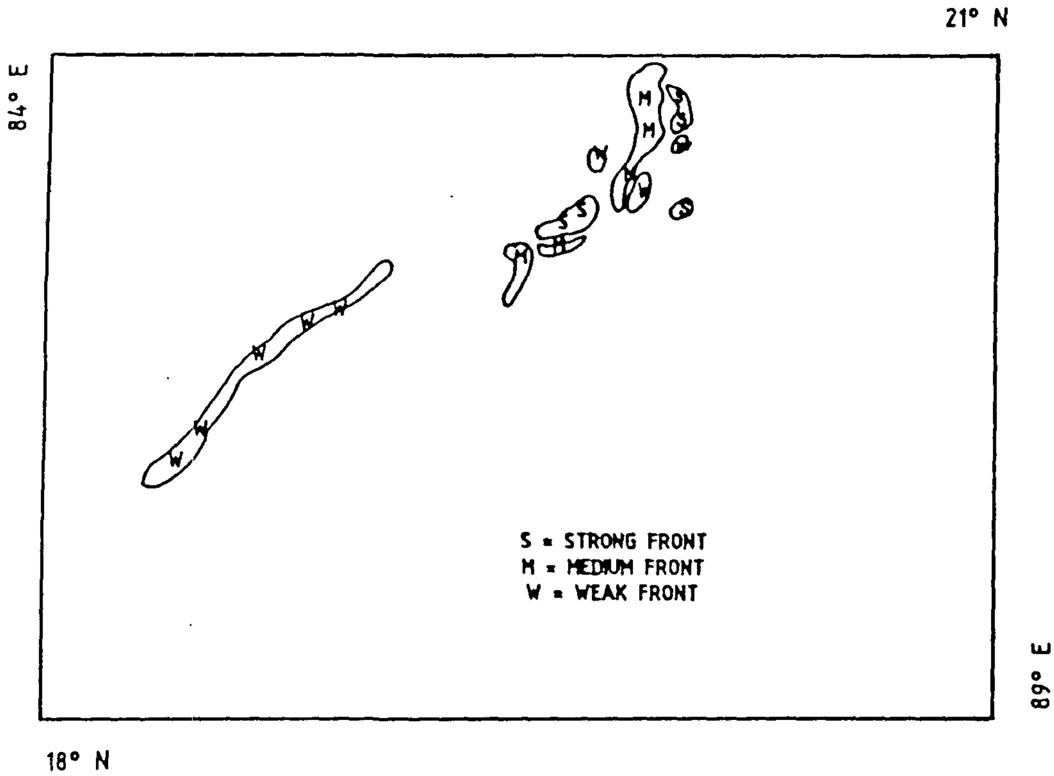


Fig. 6.42 MAP OF STRONG, MEDIUM, AND WEAK FRONTS AS FOUND IN THE STUDY AREA.

varied from 0km to 21.3875km. A map of medium fronts was made (Fig. 6.42) and was seen as patchy area between 20°-21° N and 86°30'-87°30'E, very near to the strong fronts. The area of the medium fronts on map is marked as M.

6.2.3 WEAK FRONTS

The category of weak fronts had fronts whose semi-variance ranged between 0 to 100. The minimum variance observed was 0 and the maximum variance seen was 289. The size of fronts ranged from 0.3625km to 11.9625km. Nearness to coast varied from 0km to 32.6250km. A map (Fig. 6.42) was made for the weak fronts. A few patchy zones of weak fronts were seen very near to the strong and the medium fronts i.e. in areas between 20°-21° N and 86°30'-87°30' E. Though a very long and continuous stretch of weak fronts was seen in area between 19°-20° N and 84°30'-85°45' E. The zones marked as weak front zones are represented as W in the map.

6.3 Classification Of Fish Availability Based On Frontal Zones

Based on the three frontal zones i.e strong, medium and weak fronts, the twenty-nine species of fishes had been classified qualitatively into different zones on the basis of their avail ability in these frontal zones (Table 6.2). Positive (+) sign denotes the presence of the fish in the marked frontal zone area and negative (-) sign shows their absence in the area.

Table 6.2 Fish Classification based on their availability in Frontal zones (Qualitative).

FISHES	FRONT ZONES		
	STRONG (S)	MEDIUM (M)	WEAK (W)
Skates	+	+	-
Psenus	+	+	+
Sea breams	-	-	-
Eels	+	+	+
Seer fishes	+	+	+
Silver bellies	-	-	+
Chorinemus	-	-	+
Barracudas	+	+	+
Decapterids	+	+	+
Priacanthus	+	-	-
Chirocentrus	+	+	+
Leognathids	+	+	+
Sharks	+	+	+
Clupeids	+	+	+
Dhoma	+	+	+
Upenoids	+	+	+
Karkaras	+	+	+
Squids	+	+	+
Nemipterids	+	+	+
Mackerels	+	+	+
Pomfrets	+	+	+
Catfishes	+	+	+
Ribbon fishes	+	+	+
Cuttle fishes	+	+	+
Carangids	+	+	+
Lizard fishes	+	+	+
Prawns	+	+	+
Flat fishes	+	+	+
Rays	+	+	+

+ = Present
- = Absent

Table 6.2 shows that almost all the fishes were present in some or the other front zones except sea breams which were not found in any front category. Almost all the fishes were present in strong front (S) zone except sea breams, silver bellies and chorinemus. Most of the fishes were also found in medium front (M) zone except sea breams, silver bellies, chorinemus and priacanthus. Weak front (W) zone had almost all the fishes except skates, sea breams and priacanthus.

Fine classification of all the twenty-nine species of fishes based on their availability in three fronts is presented in following five categories:

I. FISHES PRESENT IN ALL THE FRONTS i.e. IN STRONG, MEDIUM AND WEAK FRONT ZONES

Following fishes were found in all the three front zones:

1. Psenus
2. Eels
3. Seer fishes
4. Barracudas
5. Decapterids
6. Chirocentrus
7. Leognathids
8. Sharks
9. Clupeids
10. Dhoma
11. Upenoids
12. Karkaras
13. Squids
14. Nemipterids
15. Mackerels
16. Pomfrets
17. Catfishes
18. Ribbon fishes
19. Cuttle fishes

20. Carangids
21. Lizard fishes
22. Prawns
23. Flat fishes
24. Rays

II. FISHES FOUND IN STRONG AND MEDIUM FRONTS ONLY

1. Skates

III. FISHES FOUND IN STRONG FRONTS ONLY

1. Priacanthus

IV. FISHES FOUND IN WEAK FRONTS ONLY

1. Silver bellies
2. Chorinemus

V. FISHES NOT FOUND IN ANY OF THE FRONTS

1. Sea breams

It has been possible to categorise the twenty-nine fish species into various categories based on their geographical locations as evident through their catches. The frontal zones were identified using remote sensing data and GIS techniques and a frontal map was made. Comparison of fish catch with frontal maps have yielded the above given results which strongly indicate that spatial scale analysis can be utilised very effectively in locating fishery resources as it has been performed in the present case.

SUMMARY

SUMMARY

see abstract for comments

Satellite remote sensing applications and Geographical information system (GIS) techniques are becoming an important tool to tap the vast untapped reservoirs of bio-resources from our oceans. In the present context, the study entitled "Studies on coastal zone fishery resource potential using Remote Sensing and Geographical Information System techniques," envisages an amalgamation of satellite remote sensing data (particularly Indian Remote Sensing Satellite data) and the fish catch data using various GIS techniques in finding its utility for oceanic studies.

Present study suggests a new approach through a technique of identifying fronts and features as oceanic processes in the satellite derived data. Interfacing of this data along with sea-truth data yields us a wealth of information, suggestive of identifying fishery potential in the region.

The study has been carried out in a coastal zone covering nearly 11% of the total Indian coastline from 18^0-21^0N and 84^0-89^0 E in north-west Bay of Bengal in eastern India. The depth zone in the study area ranged within 30 to 300 meters. Fishery survey data, satellite data, Naval hydrographic charts and archieved data were used for the present study.

Graphic transformation of data and its overlay through data interpolation and rasterisation has been explained in two phases. Phase-I explaining the transformations done to spatio-temporal fishery survey data collected for nine months during sea cruises. Whereas, phase-II explains the transformations made to satellite data of IRS-1B LISS-I procured from National Remote Sensing Agency, Hyderabad as geo-located data in four bands in three CCT's for three different seasons and averaged.

Twenty nine fish species were selected for explaining the characteristics of fish distribution and their temporo-spatial trends. Species-wise distribution pattern for each fish species separately is explained with their spatial and temporal distribution. Month-wise occurrence of fishes in the study area is mapped on a gridded map showing their location in the area. These maps are an outcome of exhaustive GIS analysis of the fishery data to be represented in the darker to lighter shades on the map. Lighter to darker shades representing the quantity of fish catch in increasing order.

Zone-wise monthly representations of fishes are made and inter-species relationship, dominance and random patterns are explained in brief. Fish-wise monthly location maps and annual distribution pattern map for each fish species are shown in the study area.

The basic statistical technique i.e., variogram analysis used for determining spatial scales of features in the present study is explained with the help of formula used for semi-variance calculations.

Methodology for preparation of remote sensing data and preparation of data for variogram analysis has been explained. Schematic sketch representing various steps involved in variogram analysis along with figures on composites of transects and variograms are given. Through Dbase software, tables were derived from spatial scales and features and fronts were identified from the output graphs or variograms. An interpretation key was developed for variogram to obtain information as latitude, longitude, size , nearness to coast, variance difference for each feature and front for every variogram was done. Classification of spatial scales is done, into large, medium and small scales. It is supported by a number of Dbase tables. Satellite images of the study area are also presented.

Fish resources data present in the form of interpolated grid files were overlayed over each other to form groups of different categories based on their distribution and availability in the region. The seven groups thus formed are classified into very scarce, scarce, unizonal, bizonal, quadrizonal, well distributed and very well distributed. These categories showed a combination of fish species which shared almost common areas or habitats. These zones were compared and checked for the presence of any front or feature in it. The results are classified in terms of size, nearness to coast and amount of variance within their spread.

Zone-wise classification of all the fishes were done and grouped into seven categories. Each zone explains the various fishes found in them and the geographical location of these fishes. Variograms were drawn for forty transects separately for different latitudes extracted from the satellite data for the study area. Various fronts and features picked from the variograms and subsequent analysis were classified into three different classes i.e. strong, medium and weak fronts. A frontal map was drawn for all these fronts and each of these three categories of fronts were explained. Strong, medium and weak fronts were categorised in a semi-variance range between> 200 and <500 , between >100 and <200 and between 0 to 100. Each category showed different fronts in terms of their size, nearness to coast and locations.

Finally, twenty nine fish species taken up for the studies were classified into three frontal categories and their presence in strong, medium and weak fronts confirmed.

Major findings of the present work are:

1. Detection of frontal zones from synoptic satellite data, irrespective of spectral discrimination.

2. Technique of simultaneous analysis of satellite data and fishery distribution.

3. Technique of superimposition of fishery data on satellite data in raster and vector formats by way of format harmonization.

4. Relationship of frontal zones to fishery density and distribution.

5. A fishery related satellite based GIS technique which can be used as an alternative or supplementary mode to other existing methods of satellite oceanography.

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